PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS.

(INSTITUTED 1852.)

VOL. XXXIII. No. 1.

JANUARY, 1907.

Edited by the Secretary, under the direction of the Committee on Publications.

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NEW YORK 1907.

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American Society of Civil Engineers.

OFFICERS FOR 1907.

President. GEORGE H. BENZENBERG.

Vice-Presidents.

Term expires January, 1908:	*Term expires January, 1909:*
ONWARD BATES,	JOHN A. BENSEL,
BERNARD R. GREEN.	JOHN A. OCKERSON.

Secretary, CHARLES WARREN HUNT.

Treasurer, JOSEPH M. KNAP.

Directors.

Term expires January, 1908:	*Term expires January, 1909:*	*Term expires January, 1910:*
AUSTIN L. BOWMAN,	GEORGE GIBBS,	ALLEN HAZEN,
MORRIS R. SHERRERD,	J. WALDO SMITH,	GEORGE W. TILLSON.
HEZEKIAH BISSELL,	EMIL SWENSSON,	FRANK W. HODGDON,
EDWIN A. FISHER,	JAMES M. JOHNSON,	JAMES CHRISTIE,
WILLIAM B. LANDRETH,	WYNKOOP KIERSTED,	HORACE E. HORTON,
GEORGE S. PIERSON.	WILLIAM B. STOREY, JR.,	ARTHUR L. ADAMS.

Assistant Secretary, T. J. McMINN.

Standing Committees.

THE PRESIDENT OF THE SOCIETY IS *ex-officio* MEMBER OF ALL COMMITTEES.

On Finance:	*On Publications:*	*On Library:*
JOHN A. BENSEL,	MORRIS R. SHERRERD,	GEO. W. TILLSON,
GEORGE GIBBS,	ONWARD BATES,	H. BISSELL,
ALLEN HAZEN,	BERNARD R. GREEN,	JAMES CHRISTIE.
J. A. OCKERSON,	J. WALDO SMITH,	F. W. HODGDON,
GEORGE S. PIERSON.	EMIL SWENSSON.	CHAS. WARREN HUNT.

Special Committees.

ON UNIFORM TESTS OF CEMENT:—George S. Webster, Richard L. Humphrey, George F. Swain, Alfred Noble, Louis C. Sabin, S. B. Newberry, Clifford Richardson, W. B. W. Howe, F. H. Lewis.

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ON CONCRETE AND REINFORCED CONCRETE:—C. C. Schneider, J. E. Greiner, W. K. Hatt, Olaf Hoff, Richard L. Humphrey, Robert W. Lesley, J. W. Schaub, Emil Swensson, A. N. Talbot, J. R. Worcester.

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER: - - - - 5913 Columbus.
CABLE ADDRESS: - - - - - "Ceas, New York."

Vol. XXXIII. JANUARY, 1907. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

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MINUTES OF MEETINGS.

OF THE SOCIETY.

December 19th, 1906.—The meeting was called to order at 8.45 P. M.; Vice-President Kuichling in the chair; Chas. Warren Hunt, Secretary; and present, also, 114 members and 18 guests.

A paper by James D. Schuyler, M. Am. Soc. C. E., entitled "Recent Practice in Hydraulic-Fill Dam Construction," was presented by the Secretary, and discussed by Clemens Herschel, M. Am. Soc. C. E. The Secretary also presented written communications on the subject from Messrs. W. L. Butcher and T. G. Dabney.

The Secretary announced the following deaths:

PETER CHRISTIAN ASSERSON, elected Member, July 5th, 1882; died December 6th, 1906.

CHARLES HUMPHREYS, elected Member, February 1st, 1905; died November 18th, 1906.

WALLACE CLYDE JOHNSON, elected Member, October 5th, 1892; died December 15th, 1906.

Adjourned.

January 2d, 1907.—The meeting was called to order at 8.35 P. M.; President Stearns in the chair; Chas. Warren Hunt, Secretary; and present, also, 119 members and 17 guests.

The minutes of the meeting of December 5th, 1906, were approved as printed in *Proceedings* for December, 1906.

A paper by Messrs. F. S. Pearson and F. O. Blackwell, Members, Am. Soc. C. E., entitled "The Necaxa Plant of the Mexican Light and Power Company" was presented by Mr. Blackwell, and illustrated with lantern slides. The Secretary read communications on the subject from Messrs. Edwin H. Warner, F. G. Baum and H. F. Labelle.

The Secretary read a letter from G. P. Farley, M. Am. Soc. C. E., presenting to the Society a sample of a steel shaving dropped from the forging of a 16-in. B. L. rifle made at the Army Gun Factory, Watervliet Arsenal, West Troy, N. Y. This shaving, which is 50 ft. long, had been woven into the form of a basket.

The Secretary announced for the Annual Meeting the following additional excursions on Wednesday, January 16th, 1906: To the Blackwells Island Bridge, Fifty-ninth Street Power Station of the Interurban Rapid Transit Co., new Hoboken Terminal of the Delaware, Lackawanna and Western Ry. Co., and several points on the Pennsylvania Tunnel.

Ballots for membership were canvassed, and the following candidates elected:

As Members.

MADISON MOTT CANNON, Brunswick, Ga.
THOMAS FRANCIS MCCRICKETT, Detroit, Mich.
EDWIN HENRY ROGERS, Boston, Mass.
DAVID BARKER RUSHMORE, Schenectady, N. Y.
FRANCIS BETTS SMITH, Vallejo, Cal.

As Associate Members.

WILLIAM CYRUS BUNNEL, Manila, Philippine Islands.
JOSEPH REYGONDEAU DE GRATRESSE, Philadelphia, Pa.
CLIFFORD GEORGE DUNNELLS, Allegheny, Pa.
ARTHUR BENJAMIN FARNHAM, Pittsfield, Mass.
JOHN THOMPSON BISSET GELLATLY, Queenstown, Cape Colony, South Africa.

LEWIS WERNETTE HANCOCK, Louisville, Ky.
JOSEPH CHURCHILL HILTON, Brooklyn, N. Y.
EDWIN MERRIT HOLMES, Daiquiri, Cuba.
SIDNEY GARDNER JONES, Straw, Mont.
GEORGE WILLIAM LEE, Fort Edward, N. Y.
JOHN LORENZO MCCONNELL, Winona Lake, Ind.
JAMES BENNEY MCCORD, New York City.
MICHAEL JOSEPH MCDONOUGH, West Point, N. Y.
WALTER GRAY MASSENBURG, De Ridder, La.
GEORGE PILLSBURY MORRILL, Manila, Philippine Islands.
ROBERT COLLYER NOERR, Hartford, Conn.
JAMES HERBERT RICHARDSON, New York City.
FRANK MINER ROBINSON, Quincy, Cal.
ERNEST WILLIAM SCHODER, Ithaca, N. Y.
JOHN WELLINGTON STEWART, Raleigh, N. C.
RUSSELL SUTER, New York City.
NELSON OTIS TIFFANY, JR., Buffalo, N. Y.
WALDO GILMAN WILDES, Albany, N. Y.

The Secretary announced the following deaths:

GEORGE CECIL KENYON, elected Associate Member, April 4th, 1900; Member, June 6th, 1905; died October 30th, 1906.

ALBA FISK BROWN, elected Member, September 7th, 1887; died April 22d, 1906.

Adjourned.

January 16th, 1907.—The minutes of this, the Annual Meeting, will be printed in the *Proceedings* for February, 1907.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, February 6th, 1907.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper entitled "Lighthouse Construction in the Philippines," by Spencer Cosby, M. Am. Soc. C. E., will be presented for discussion.

This paper was printed in *Proceedings* for November, 1906.

Wednesday, February 20th, 1907.—8.30 P. M.—At this meeting two papers will be presented for discussion, as follows: "Rainfall, and Run-Off in Storm-Water Sewers," by Charles Emerson Gregory, Assoc. M. Am. Soc. C. E.; and "The Design of the New Croton Dam," by Edward Wegmann, M. Am. Soc. C. E.

The paper by Mr. Gregory was printed in *Proceedings* for November, 1906; Mr. Wegmann's paper is printed in this number of *Proceedings*.

Wednesday, March 6th, 1907.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper entitled "Uniformity of Requirement and Clearness of Specification in Agreements for the Graduation of Railroads," by W. F. Dennis, M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings*.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all meetings:

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Society of Engineers, 17 Victoria Street, Westminster, S. W., England.

American Institute of Mining Engineers, 99 John Street, New York City.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Civil Engineers' Club of Cleveland, 1200 Scofield Building, Cleveland, Ohio.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa.

Engineers' Society of Western Pennsylvania, 803 Fulton Building, Pittsburg, Pa.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

Louisiana Engineering Society, 604 Tulane-Newcomb Building, New Orleans, La.

Engineers' Club of Central Pennsylvania, Corner Second and Walnut Streets, Harrisburg, Pa.

Engineers' and Architects' Club of Louisville, Ky., 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

Teknisk Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Société des Ingénieurs Civils de France, 19 Rue Blanche, Paris, France.

Svenska Teknologförenigen, Brunkebergstorg 18, Stockholm, Sweden.

Institute of Marine Engineers, 58 Romford Road, Stratford, London, E., England.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Pacific Northwest Society of Engineers, 617–618 Pioneer Building, Seattle, Wash.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Memphis Engineering Society, Memphis, Tenn.

Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

The Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Institution of Engineers of the River Plate, Buenos Aires, Argentine Republic.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Cleveland Institute of Engineers, Middlesbrough, England.

Civil Engineers' Society of St. Paul, St. Paul, Minn.
Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.
Rochester Engineering Society, Rochester, N. Y.

SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

In reference to this work, a summary of all searches made to date will be found in the Appendix* to the Annual Report of the Board of Direction for the year ending December 31st, 1906.

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

San Francisco, Cal.

(Abstract.)

December 19th, 1906.—The tenth regular meeting of the San Francisco Association of Members, Am. Soc. C. E., was held; Edwin Duryea, Jr., President, in the chair; Franklin Riffle, Secretary; and present, also, 30 members and 3 guests.

The minutes of the previous meeting were read and approved.

It was decided to print and send to each member a brief summary of each meeting.

* Page 20.

The following officers were elected:

President, A. L. ADAMS.
Vice-President, CHARLES DERLETH, JR.
Secretary, FRANKLIN RIFFLE.
Treasurer, J. D. GALLOWAY.

The Report of the General Committee on Earthquake Effects was presented, and also the letter of the President transmitting the reports of the several Earthquake Committees.

The paper by A. L. Adams, M. Am. Soc. C. E., entitled "Additional Information on the Durability of Wooden Stave Pipe," printed in *Proceedings* for September, 1906, was discussed by Messrs. Adams, Howells, Marx, Duryea, Galloway, A. M. Hunt, Wagoner, and Harroun.

The paper by James D. Schuyler, M. Am. Soc. C. E., entitled "Recent Practice in Hydraulic-Fill Dam Construction," printed in *Proceedings* for October, 1906, was discussed by Messrs. Howells, Marx, Duryea, Wing, Galloway, Haehl, and Wagoner.

Adjourned.

ANNUAL REPORT OF THE BOARD OF DIRECTION FOR THE YEAR ENDING DECEMBER 31ST, 1906.

PRESENTED AT THE ANNUAL MEETING, JANUARY 16TH, 1907.

The Board of Direction, in compliance with the Constitution of the Society, presents its report for the year ending December 31st, 1906.

MEMBERSHIP.

The changes in membership are shown in the following table:

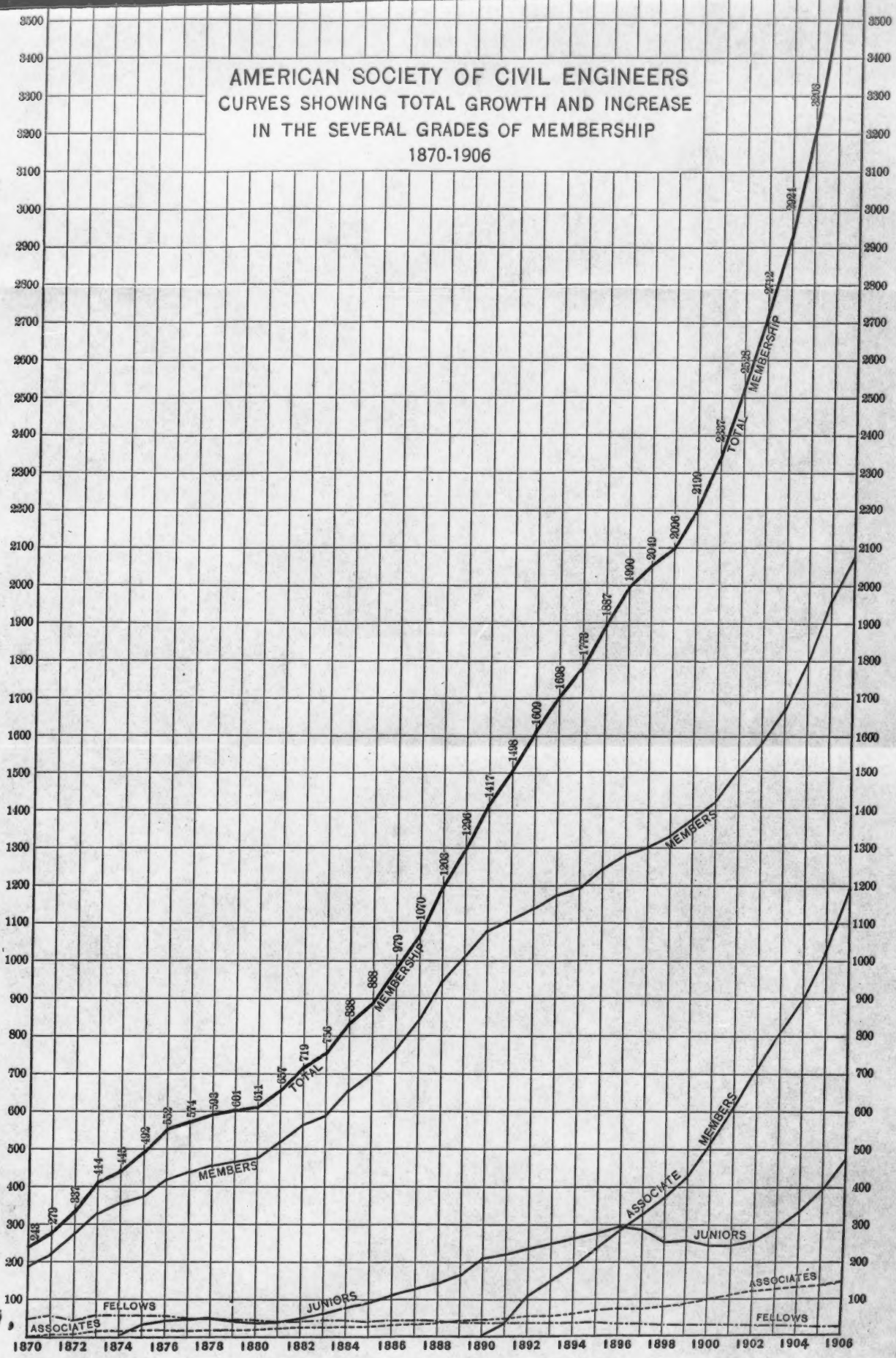
GRADE.	JAN. 1ST, 1906.			JAN. 1ST, 1907.			LOSSES.				ADDITIONS.		TOTALS.	
	Resident.	Non-Resident.	Total.	Resident.	Non-Resident.	Total.	Transfer.	Resignation.	Dropped.	Death.	Transfer.	Election.	Loss.	Gain.
Honorary Members	1	11	12	2	9	11	....	..	..	1	....	....	1	....
Corresponding Members	....	2	2	....	2	2	....	..	..	..	....	....	....	....
Members	420	1 532	1 952	451	1 624	2 075	....	5	7	29	*53	111	41	164
Associate Members	285	736	1 021	309	886	1 195	51	2	3	7	†48	189	63	237
Associates	52	79	131	54	88	142	2	1	2	2	2	16	7	18
Juniors	119	277	396	138	330	468	50	3	15	2	....	142	70	142
Fellows	9	16	25	9	15	24	....	..	..	1	....	....	1	....
Total	886	2 653	3 539	963	2 954	3 917	103	11	27	42	103	458	183	561

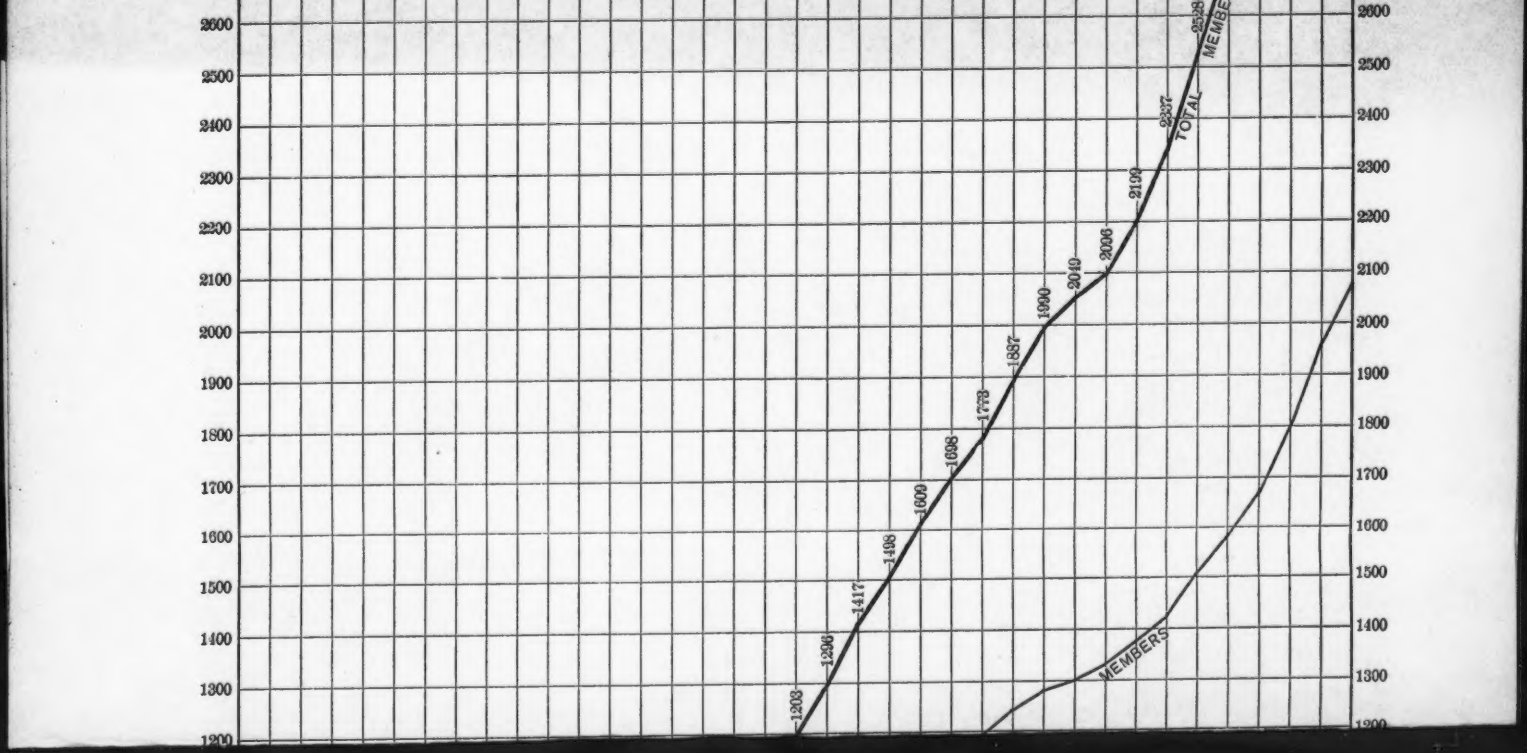
*51 Associate Members, 1 Associate and 1 Junior.
†1 Associate and 47 Juniors.

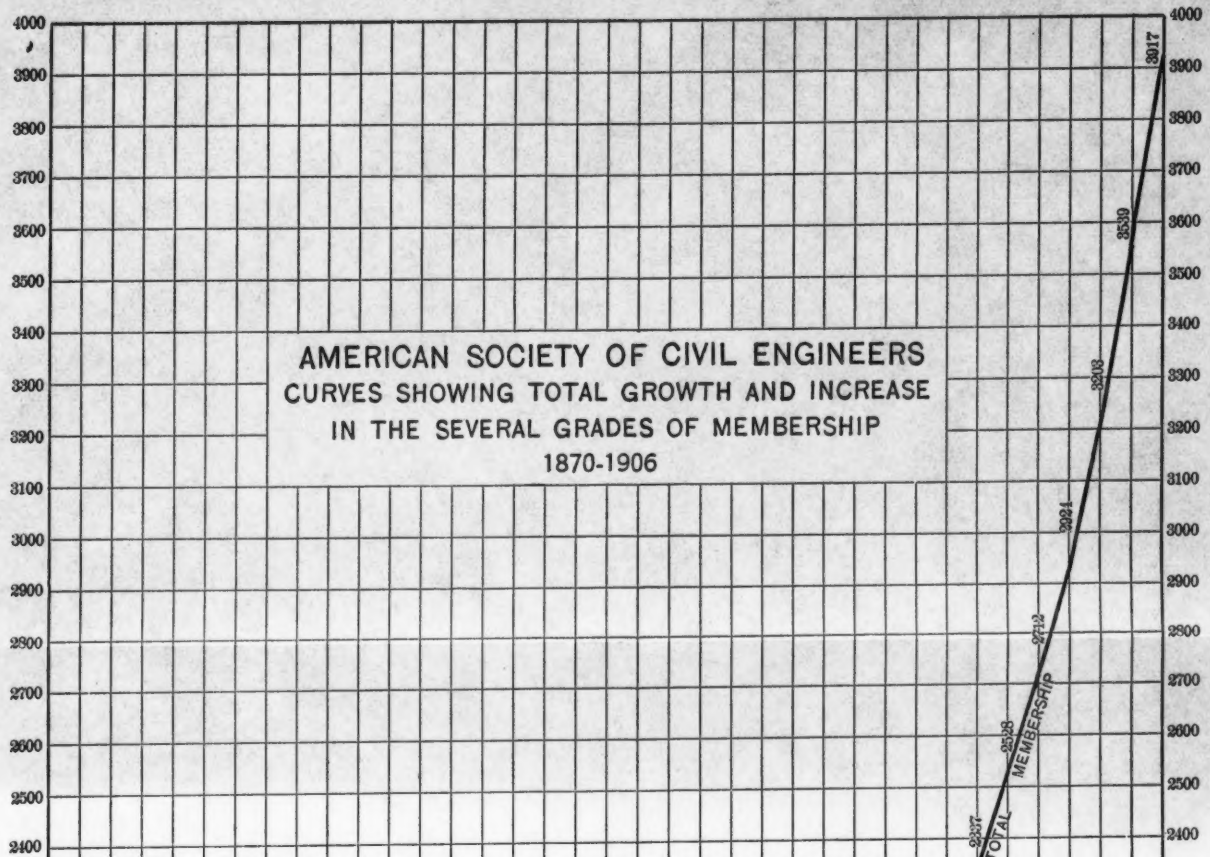
It will be seen that the net increase during the year has been 378, which is 42 greater than last year's increase, and 99 greater than that of the previous year. The average annual increase in membership during the last four years has been 301.

Appended to this report will be found a diagram of the membership, prepared by the Secretary, showing curves of the total membership, and the number in each grade, from 1870 to 1906, inclusive. It is believed that a study of this diagram will be found of interest.

The total number of applications received during the year was 635; 516 being for admission, and 119 for transfer.


AMERICAN SOCIETY OF CIVIL ENGINEERS
CURVES SHOWING TOTAL GROWTH AND INCREASE
IN THE SEVERAL GRADES OF MEMBERSHIP
1870-1906
TOTAL MEMBERSHIP
MEMBERS
ASSOCIATE MEMBERS
JUNIORS
ASSOCIATES
FELLOWS
ASSOCIATES
JUNIORS
FELLOWS
MEMBERS
918
970
837
1114
1445
1492
1552
1574
1593
1601
1611
1657
1719
1756
1838
1883
1970
2070
2303
2636
2900
3021
3208
2337
2528
2712
2210
2006
2010
1900
1887
1778
1698
1600
1498
1417
1206
1303
1070
970
883
838
756
719
657
611
601
593
574
552
492
445
414
337
270
918


2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1203
1296
1417
1498
1609
1698
1773
1887
1990
2040
2096
2199
2327
2528
TOTAL MEMBERS
MEMBERS


AMERICAN SOCIETY OF CIVIL ENGINEERS
CURVES SHOWING TOTAL GROWTH AND INCREASE
IN THE SEVERAL GRADES OF MEMBERSHIP
1870-1906
TOTAL MEMBERSHIP
4000
3900
3800
3700
3600
3500
3400
3300
3200
3100
3000
2900
2800
2700
2600
2500
2400
2337
2528
2712
3021
3208
3539
3917

The losses by death reported during the year number 42. They are as follows:

Honorary Member: Robert Bennett Gorsuch.

Members: Arthur Vaughan Abbott, Peter Christian Asserson, Carl Christian Adolph Both, Alba Fisk Brown, James Abercrombie Burden, Robert Bruce Burns, John Eugene Cheney, Freeman Clarke Coffin, John James Robertson Croes, Dunkin Wirgman Hemming, Charles Humphreys, Jones Mumford Jackson, William Tyndale Jennings, Wallace Clyde Johnson, George Cecil Kenyon, Jacob Hays Linville, James Loring Lusk, Kyoichi Murakami, George Benson Nicholson, Charles Paine, Henry Williams Parkhurst, William Thomas Pierce, David Ashley Poynor, George Henry Robinson, Felician Slataper, Francis Edward Snyder, Samuel Spencer, George Tatnall, George Y. Wisner.

Associate Members: Joseph Hockman Bowman, Per Brynn, Arthur Price Law, Elver La Zelle Shinbur, Moses Hannibal Wright, Eddy Elbert Young, Albert Henry Zeller.

Associates: William Gibson, Jr., Charles Louis Spier.

Juniors: Frederick Appel Hausman, Benno Rohnert.

Fellow: Edward Cooper.

LIBRARY.

The total contents of the Library, and the increase during the year, are shown in the following table:

	Total Contents.	Increase during 1906.
Bound volumes	15 110	652
Unbound volumes	30 208	1 384
Specifications	6 366	97
Maps, photographs and drawings	3 818	136
Total	55 502	2 269

Of these accessions, 414 were donations received in answer to special requests; 80 were donations from publishers; 1 636 were donations received in regular course, and 139 were purchased.

The total number of titles in the Library is now 21 687.

The value of accessions to the Library during the year is as follows, each accession having been valued separately as received:

2 130 Donations and exchanges (estimated value)	$1 651.07
139 Volumes purchased (cost)	495.78
Binding 148 volumes	166.40
Total	$2 313.25

The following amounts have been expended upon the Library during the year:

Purchase of books	$495.78
Express charges, etc	21.15
Binding	166.40
Fixtures, supplies and sundries	71.09
Total	$754.42

The use of the Reading Room and Library during 1906 shows a gratifying increase over previous years. 3 500 persons registered in the Reading Room during the year, or about 100% more than the average annual attendance during the first five years' occupancy of the present house.

73 new searches (containing 2 522 separate references) have been made during the year, and 8 searches made in previous years have been brought up to date, and copies of them furnished. The total cost of these searches, paid by members and others for whom they were undertaken, was $436.51, or an average cost per search of $5.39.

In order to show the character of this work, and because it may be of value to members to know what subjects have already been covered, a list of the searches made to date has been prepared and is printed as an appendix to this report.

PUBLICATIONS.

During the year ten numbers of *Proceedings* have been issued regularly, and two volumes of *Transactions* have appeared.

In the *Proceedings* the list of references to current engineering literature has covered 77 pages, and contains 3 286 classified references to 83 periodicals.

The stock of the various publications of the Society kept on hand for the convenience of members and others, now amounts to 137 306 copies, the cost of which to the Society, for paper and press work only, has been $18 182.96. The sales of publications have been much greater than heretofore.

During the year, 4 132 volumes of *Transactions* have been bound for members and others in the standard half-morocco and cloth bindings.

The Society is to be congratulated on the variety and scope of the professional papers and discussions published during the year, which have covered problems in Structural, Hydraulic, Municipal, Sanitary, Naval, Electrical, Railway, and Mining Engineering, and also on Educational and Legal matters, and have discussed, among

other subjects, Lighthouses, Rainfall and Run-Off, Continuous Columns, Eye-Bars, Municipal Refuse and Garbage Disposal, Overloaded Bridges, Wooden Stave Pipe, Filtration of Water Supplies, Sewage Disposal, Steam and Electrical Operation for Trunk Lines, River Regulation, Canal Building, Tunnel Construction and Ventilation, Flow of Water in Pipes, Engineering Education, Patents, Street Traffic, Materials of Construction, Electric Light and Power Plants, Dam Construction, Naval Coaling Stations, and Hydraulic Mining.

SUMMARY OF PUBLICATIONS FOR 1906.

	Issued.	Edition.	Total Pages.	Plates.	Cuts.
Transactions (Volumes)*	2	4 125	1 048	74	145
Proceedings (Monthly Numbers)	10	4 125	1 535	121	168
Constitution and List of Members	1	4 550	270	...	1
Total	13	....	2 853	195	314

The cost of publications has been:

For Paper, Printing, Binding, etc., *Transactions* and *Proceedings*	$12 235.95
For Plates and Cuts	1 854.79
For Boxes, Mailing Lists, Copyright and Sundry Expenses	335.67
For 6 700 Extra copies of Memoirs and Papers	654.65
For List of Members	1 288.17
Total	$16 369.23
Deduct amount received from sale of publications	3 578.14
Net cost of publications for 1906	$12 791.09

INTERNATIONAL ENGINEERING CONGRESS OF 1904.

As a suitable memorial of a very interesting occasion, the Board last year authorized the Library Committee to have prepared and erected a bronze tablet commemorative of the International Engineering Congress, held under the auspices of this Society in St. Louis in 1904.

* Includes Indexes and Tables of Contents.

During this year, this tablet was designed and cast, and has now been erected in the Library of Washington University.* The cost of the Tablet was $230.

MEETINGS.

During the year, 26 meetings have been held, as follows: At the Annual Meeting, 2; at the Annual Convention, 5; and 19 other meetings held at the Society House.

At these meetings there were presented 22 formal papers, 6 of which were illustrated with lantern slides, besides which there were 5 topical discussions and one illustrated lecture.

The Thirty-eighth Annual Convention was held at the Hotel Frontenac, Thousand Islands, N. Y., and was well attended and enjoyable.

The total registered attendance at all the meetings during the year was 3 643. This figure includes 605 at the Annual Meeting, and 369 at the Annual Convention, but it is not a complete statement of the total attendance, inasmuch as some members and many guests, notably at the Annual Meeting, were not registered.

MEDALS AND PRIZES.

For the year ending with the month of July, 1905, Prizes were awarded as follows:

The Norman Medal to C. C. Schneider, Past-President, Am. Soc. C. E., for his paper entitled "The Structural Design of Buildings."

The Thomas Fitch Rowland Prize to Charles L. Harrison, M. Am. Soc. C. E., and Silas H. Woodard, M. Am. Soc. C. E., for their paper entitled "Lake Cheesman Dam and Reservoir."

The Collingwood Prize for Juniors to E. P. Goodrich, Jun. Am. Soc. C. E. (now M. Am. Soc. C. E.), for his paper entitled "Lateral Earth Pressures and Related Phenomena."

SOCIETY HOUSE.

In the last report of the Board a general statement of the contract which had been entered into for the construction of the addition to the Society House was made, and the enlarged quarters were described. At that time the building was not finished, although it was put in shape for use during the last Annual Meet-

*For description of this tablet see *Proceedings*, Vol. XXXII, page 229.

ing. During 1906 the building has been completed and paid for.* The Building Committee, Messrs. Alfred Noble, S. L. F. Deyo, N. P. Lewis, and Chas. Warren Hunt, has made its final report to the Board, showing that the total cost of the addition to the building was $61 430.30. The estimated cost was $60 000. The painting and decoration of the addition have been deferred until the walls are thoroughly seasoned. This work has been authorized by the Board, and will be taken up soon after the Annual Meeting, and the old portion of the house will be redecorated at the same time.

LOCAL ASSOCIATIONS OF MEMBERS.

Although, as stated in the last report of the Board, Local Associations of Members of the Society were organized at Kansas City, Mo., Memphis, Tenn., and San Francisco, Cal., no active work of these Associations has been reported to the Board during the year, except in the case of the San Francisco Association.

This Association has been active since its formation. A number of meetings for the discussion of papers published by the Society, and for other purposes, have been held, and it has done excellent work since the San Francisco Earthquake disaster of April 18th, 1906. Although the organization as a body did not assist in making the plans for the reconstruction of the city, seven of its members were appointed by the Mayor of San Francisco on the "Committee of Forty," and these members took an important part in the formulation of the plans for reconstruction which were made at that time.

The Association as a body devoted its attention to a study of the earthquake effects, with a view to bringing out needed improvements in the design of engineering works.

To this end, a General Committee and the following Special Committees were appointed: On Geology of the Earthquake; On Fire and Earthquake Damage to Buildings; On Water-Works; On Light, and Street Railway Transportation; On Sewers; On Railway Structures; and On Highway Structures.

These Committees have collected data and studied the physical effects of the earthquake and fire, and their reports, which are fully illustrated, have been forwarded to the Secretary of this Society, and will soon be published in *Proceedings* for the information of, and discussion by, the membership in general.

*For a full description of the property of the Society see report of the Secretary to the Annual Convention, June, 1906, *Proceedings*, Vol. XXXII, page 227.

SAN FRANCISCO DISASTER.

Shortly after the earthquake disaster at San Francisco in April, 1906, the Secretary of the Technical Society of the Pacific Coast, in a communication to the Secretary of this Society, urged that the engineers of San Francisco were in need of engineering instruments, office supplies, etc. The matter was brought before a meeting of the Society, and, under its authorization, the Secretary purchased a supply of such articles as seemed most appropriate, and forwarded them promptly. It is understood that their distribution materially aided many engineers at a time when it would have been difficult, if not impossible, for them to procure such supplies in any other way.

FINANCES.

The attention of members is invited to the Secretary's statement of receipts and disbursements, and to the general balance sheet which accompanies it, in which the very satisfactory financial condition of the Society appears.

To show this sound financial condition, it is only necessary to point out that, notwithstanding the fact that during the year the extraordinary receipts only amounted to $100, and the extraordinary disbursements for Building, Commemorative Tablet, relief of San Francisco Engineers, payment of temporary loan, etc., amounted to $29 234.13, the cash balance on hand is as large as it was at the beginning of the year.

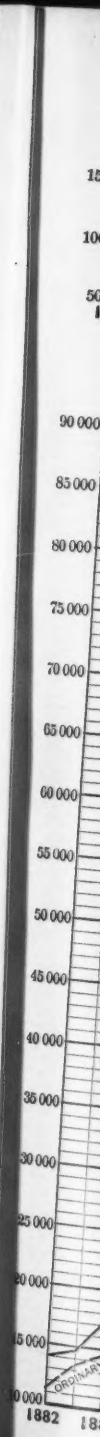
A diagram showing the ordinary receipts and disbursements of the Society for each year from 1882 to 1906 (inclusive) is given on the following page.

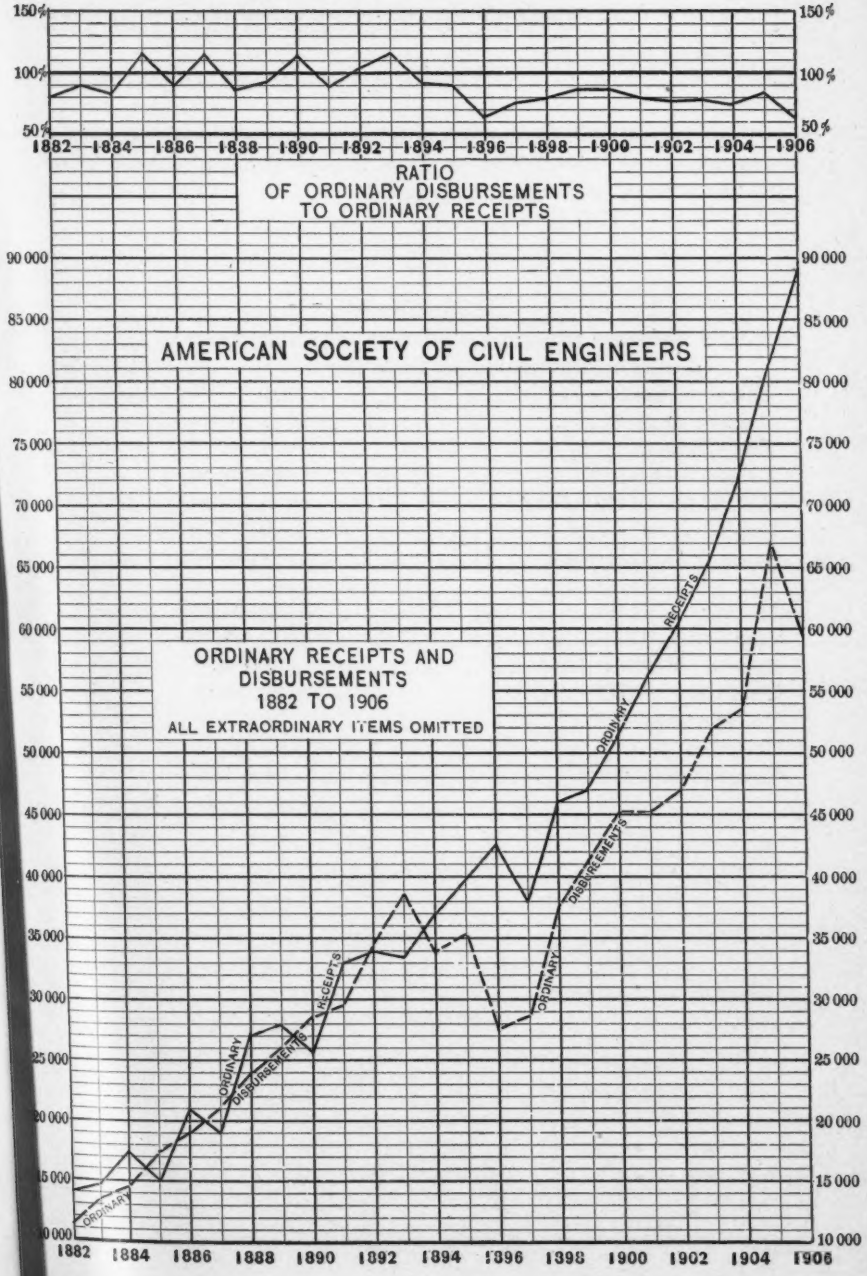
The reports of the Secretary and Treasurer are appended.

By order of the Board of Direction.

CHAS. WARREN HUNT,
Secretary.

NEW YORK, JANUARY 3D, 1907.




150%
100%
50%
1882 1884 1886 1888 1890 1892 1894 1896 1898 1900 1902 1904 1906
RATIO
OF ORDINARY DISBURSEMENTS
TO ORDINARY RECEIPTS
90 000
85 000
80 000
75 000
70 000
65 000
60 000
55 000
50 000
45 000
40 000
35 000
30 000
25 000
20 000
15 000
10 000
AMERICAN SOCIETY OF CIVIL ENGINEERS
ORDINARY RECEIPTS AND
DISBURSEMENTS
1882 TO 1906
ALL EXTRAORDINARY ITEMS OMITTED
ORDINARY
RECEIPTS
ORDINARY
DISBURSEMENTS

REPORT OF THE SECRETARY, FOR THE

To the Board of Direction of the

Gentlemen:—I have the honor to present a statement of Re-
December 31st, 1906. I also append a general balance sheet show-

New York, January 2d, 1907.

Receipts.

Balance on hand December 31st, 1905, in Bank, Trust Company and in hands of Treasurer		$12 957.25
Entrance Fees	$10 815.00	
Current Dues	42 898.14	
Past Dues	1 749.78	
Advance Dues	19 535.49	
Certificates of Membership	438.44	
Badges	2 313.70	
Sales of Publications	3 566.24	
Interest	80.04	
Library	407.85	
Convention	3.00	
Annual Meeting	1 024.00	
Binding	4 754.42	
Miscellaneous	171.58	
Donation	100.00	
Compounded Dues	1 075.00	
		$88 932.68
		$101 889.93

YEAR ENDING DECEMBER 31st, 1906.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

ceipts and Disbursements for the fiscal year of the Society, ending
ing the condition of the affairs of the Society.

Respectfully submitted,

CHAS. WARREN HUNT,
Secretary.

DISBURSEMENTS.

Salaries of Officers	$8 799.96	
Clerical Help	11 368.29	
Caretaking	1 786.19	
Publications	16 358.58	
Postage	4 102.43	
General Printing and Stationery	2 294.53	
Badges	1 851.35	
Certificates of Membership	307.80	
Binding	2 241.32	
Library	754.42	
Maintenance of House	126.13	
Heat, Light and Water	1 523.26	
Furniture	966.99	
Annual Meeting	2 117.45	
Convention	877.68	
Prizes	187.10	
Interest and Insurance	3 707.50	
Petty Expenses	161.19	
Building	24 587.02	
Refunds	72.66	
Current Business	734.07	
Payment Temporary Loan	3 000.00	
Relief San Francisco Engineers	450.12	
Tablet Commemorative of Int. Eng. Cong.	230.00	
		$88 606.04
Balance on hand December 31st, 1906:		
In Union Trust Company	$475.55	
In Garfield National Bank	11 308.34	
In hands of Treasurer	1 500.00	
		13 283.89
		$101 889.93

GENERAL BALANCE SHEET, DECEMBER 31ST, 1906.

ACCOMPANYING THE REPORT OF THE SECRETARY.

ASSETS.		
Three Lots (estimated value)		$270 000.00
Society Building (cost)		165 054.13
Furniture (cost)		17 501.93
Publications on hand (inventoried cost value)		18 182.96
Library:		
Cash expended for Books, etc.	$10 600.54	
Donations, estimated value	47 055.59	
		57 656.13
Due from Members	$ 1 568.46	
Due from Non-Members	590.66	
		2 159.12
Cash		13 316.11
		$543 870.38

LIABILITIES.		
Dues for 1907 paid in advance		$ 19 535.49
Mortgage Debt		175 000.00
Accrued Interest		3 500.00
Accounts Payable		233.30
Funds invested in Society House, Lots and Library	$ 26 730.78	
Surplus	318 870.81	
		345 601.59
		$543 870.38

We have examined the books and accounts of the American Society of Civil Engineers, and certify that the foregoing Balance Sheet is in accordance therewith, as at December 31st, 1906; and, in our opinion, correctly states the condition of the Society's affairs, as shown by the books at that date.

79 WALL STREET, NEW YORK.
JANUARY 11TH, 1907.

MARWICK, MITCHELL & Co.,
Chartered Accountants.

REPORT OF THE TREASURER.

In compliance with the provisions of the Constitution, I have the honor to present the following report for the year ending December 31st, 1906:

Balance on hand December 31st, 1905			$12 957.25
Receipts from current sources, January 1st to December 31st, 1906			88 832.68
Extraordinary receipts—Donation			100.00
Payment of Audited Vouchers for Current Business, January 1st to December 31st, 1906		$59 371.91	
Extraordinary Expenses on Account of:			
Building and Furniture	$25 554.01		
Payment Temporary Loan	3 000.00		
San Francisco Relief	450.12		
Tablet Commemorative of International Engineering Congress, 1904	230.00		
		29 234.13	
Balance on hand December 31st, 1906:			
In Union Trust Company	$475.55		
In Garfield National Bank	11 308.34		
In hands of the Treasurer	1 500.00	13 283.89	
		$101 889.93	$101 889.93

Respectfully submitted,

Jos. M. Knap,
Treasurer, Am. Soc. C. E.

New York, January 2d, 1907.

RECEIVED DECEMBER 31ST, 1906.

APPENDIX
TO ACCOMPANY ANNUAL REPORT OF THE BOARD OF DIRECTION.

Classified List of Subjects of Library Searches:

January, 1902, to December, 1906.

BRIDGE.

Melan Arch Bridge Construction.
Drawbridges in Harbors.
Bridges and Tunnels on Mountain Divisions of Transcontinental Lines.
Specifications for Blair and Glasgow Bridges.
Obstruction of Bridges to the Flow of Water.
Pressure on Foundations.
Plate-Girders for Bridges.
Gradient of Roadways of Bridges at Memphis, St. Louis, St. Charles, and Omaha.
Use of Reinforced Concrete in Arches, Abutments and Retaining Walls.
N. Y. C. & H. R. R. R. Passenger Bridge at Albany (Maiden Lane Bridge).

ELECTRICAL.

Cost of Large Steam-Electrical Power Plants.
Diagrams of Hourly Distribution of Power for Electric Lighting and Railway Service.
Steam Turbines, Hydro-Electric Installations and Masonry Dams.
Electric Conduits and Subways.

MARINE.

Loading Cattle on Steamboats.
Japanese Shipbuilding and Docks.
Dimensions of Dry Docks on the Atlantic Coast Large Enough for Trans-Atlantic Steamers.

MECHANICAL.

Central Control of Valves in Steel Works.
Smoke Prevention.
Tests of Hooks and Shackles.
Central Refrigerating Installations.
Kilns.
List of Iron and Steel Works in Germany.
Acetylene Gas.
Mond Process of Gas Production.
Passenger and Freight Elevators.
Jib Cranes.
Centrifugal Pumps, January, 1900, to April, 1905, inclusive.
Holding Power of Anchor Bolts in Rock.
Coal Handling Machinery.
Coal Storage Plants.
Coal Tipples.
Sand-Lime Process of Making Brick.
Tramways for Lumbering.
Operation of Steam Shovels.
Friction Losses of Liquids Other than Clean Water.
Tower Derricks.
Holding Power of Drift-Bolts.

METALLURGICAL.

Smelting and Ferro-Titanium. Articles by A. J. Rossi.
Furnaces, Furnace Plants and Rolling Mills (Books).
Bibliography on the Nodulising and Desulphurisation of Fine Ores and Pyrite Cinders.

MINING.

Kind and Chaudron Method of Shaft Sinking Through Water-Bearing Solids.
Dredging of Auriferous Sand and Gravel.
Poetsch Freezing Process.
Annual Production and Value of Phosphate Rock in the U. S. from 1890-1903.

MISCELLANEOUS.

List of Technical Books for a General Library to Cost about $250.
Method of Finding Center of Population.
Selected List of Engineering Indexes.
"Hardpan" (Definition of).
"Gumbo" (Definition of).
Geologic History of Manhattan Island and Long Island.
Forest Preservation.
Ethics for Civil Engineers.
List of Books on Civil Engineering for a Small Library.
Dictionaries Containing Technical and Engineering Terms.
Civil Service.
Pipe Lines and Tanks for Oil Supplies.
Do the Field Notes of an Engineer Belong to the Employer or the Employee?
Meaning of the Terms "Net Section" and "Neat Section."
List of American Publications on Water Supply of Towns, Irrigation, Hydraulic Machinery, Practical Bridge Designing, Practical Tunneling, Railway Signaling, Railway Permanent Way Material and Construction, Road and Street Design and Construction, and Electric Traction.

MUNICIPAL.

Paving Brick Tests.
House Numbering Systems.
Statistics of Macadam and Other Street Paving.
Municipal Ownership.
Use of Crude Petroleum on Roads.
Wood Pavements.

RAILROAD.

Ventilation and Construction of Tunnels.
Construction and Cost of Long Railroad Tunnels.
English Channel Tunnel.
Resistance on Railroad Curves (Formulas).
Train Resistance.
Freight Traffic in New York City.
Concrete and Steel-Concrete Ties.
Reinforced Concrete Ties.
Railroad Terminals.
Railroad Signaling and Interlocking.
Sand Track (Derailing device).
Selected Bibliography on Rails.
Systems of Maintenance of Way Bookkeeping in Use on Railroads.
Cost of Transferring Freight Cars by Ferry.
Narrow-Gauge Railroads.
Reinforced Concrete in Railway Work.
Taxation and Valuation of Railways.
Maximum Curves and Grades.
Tonnage Rating of Locomotives as Affected by the Length of Ruling Grades.
The Barschall Rail Joint.
Ballast.
Ship Railways.
Grade Crossings.
Rack-Rail Systems.

RAILROAD, STREET.

Contract Prices of Electric Conduit, Street Railways.
Cross sections of Subways, Berlin and Paris.
On the Use of Tee-Rails by Surface Railroads, Particularly in Connection with Brick Paving.
Details and Design of Structural Steel in Elevated Railroads.
Experimental Lines Built to Prove the Feasibility of Elevated Railroads.
Inclined Planes in Use on Street Railways.

SANITARY.

Relation of Run-Off to Rainfall in Sewer Districts.
Concrete Sewers.
Sewer Gauging.
Sewage Disposal. List of Recent Books, January 10th, 1903.
Charcoal Filter Used in Sewage Disposal.
Scott-Moncrieff System of Sewage Disposal.
Irrigation and Filtration Methods of Sewage Disposal.
Septic Tanks and Sewage Filtration Beds.
Ducat Oxygen Process of Sewage Disposal.
Steam Heating Plants: Capacity about 8 000 000 cubic feet of air.
Central Heating Stations in the United States.
Odors and Gases from Rendering and Garbage Disposal Works.
Refuse Destroyers in the United States.
Caisson Disease.
Land Reclamation.
Nuisances from Gas-Works Refuse and Treatment of the Same.
Tests of the Strength of Vitrified Sewer Pipe.
Design and Construction of Cooling Tanks.
Sewage Purification: Methods, Maintenance and Results.

STRUCTURAL.

Durability of Wood Under Water: Data and Statistics.
Concrete Piles.
Water Jet for Sinking Caissons and Piles.
Coffer Dams and Deep Foundations.
Preservation of Timber.
Iron Pipe in Structural Work.
Modern Steel-Frame High Buildings.
Protected Steel Columns in Fires.
Wakefield Sheet-Piling.
Comparative Test of Various Paints.
Forms for Concrete Masonry.
Corrosion of Iron and Steel.
Design and Requirements of Horse Stables.
Injection of Grout into Water-Bearing Strata.
Concrete Floors for Loads of over 250 lb. per sq. ft.
Steel-Concrete Construction (Papers by A. L. Johnson).
Steel or Expanded Metal Used in Walls of Concrete to Prevent Cracking.
Reinforced Concrete Columns.
Sea Water for Mixing Concrete.
Disintegration of Concrete in Sea Water.
Methods Used by the Romans in Making Mortar or Concrete.
Placing of Concrete under Water.
The Use of Broken or Crushed Brick as an Aggregate in Concrete.
Comparative Merits of Cast-Iron and Steel Columns.
Cast-Iron Column Tests.
Concrete-Steel Construction.
German and French Tests and Specifications for Portland Cement.
Laying Concrete Mortar in Cold Weather: Search in *Transactions* Am. Soc. C. E.
Tests of Cement Mortar Mixed with Sand in Different Proportions.
Crazing of Cement.
Effects of Sea Water on Cement.
Analysis of Puzzolanic Cements.
Comparative Tests of Portland Cement Made at Different Temperatures.
Keene's Cement.
Concrete-Metal Construction.
Collapse of Buildings.
Steel Construction for large Buildings.
Disposition of Structures to Meet Æsthetic Considerations.
Specifications for Paint for Railway Bridges and Buildings.
Grain Elevators.
Pile Driving (Iron and Steel).
Tests of Various Forms of Steel to Find the Modulus of Elasticity.
Tests of Twisted Bars of Steel, for Elongation.
Comparative Tests of Different Systems of Reinforced Concrete.
Deterioration of Steel, Wood, or Masonry Structures.

TOPOGRAPHICAL.

Magnetic Declination in Mexico.
Methods of Treating Street Intersections.
Photographic Surveying.

WATER SUPPLY AND WATER POWER.

Tests of Cement Pipe.
Steel-Concrete and Wood-Stave Pipe Conduits.
Reinforced Concrete Conduits and Penstocks 8 ft. in Diameter and greater.
Concrete Construction before 1897 (Dams and Hydraulic Work).
Methods of Laying Concrete in Dams 40 ft. High and Greater.
Appraisal and Valuation of Water-Works.
Right of Eminent Domain (Water-Works).
Consumption of Water per Capita.
Water Towers.
Water Waste Prevention.
Recent Developments of Water Powers of Large Size and High Heads; April, 1904.
Cost of Operation, etc., of Power Plants.
Description of Great Northern Paper Co. Plant at Millinocket, Me. (Water Power).
Cost of Development, and Rental of Water Power in North America.
Small Water Power Plants of the Past Eight Years; 1897-1905.
Utilization of the Ebb and Flow of Tide for the Generation of Power.
Utilization of the Rise and Fall of Tide for the Generation of Power.
Utilization of the Power of Ocean Waves.
Water Power Developments.
Water Power Development, 4 000 h. p. and Greater (1904-1906).
Design, Construction and Cost of Large Flumes.
Intake Tunnels at Cleveland and Chicago.
Effect of Storage of Ground-Water in Open Reservoirs.
Sand Washing and Pumping.
Construction and Operation of Water-Conduit Tunnels.
Submerged Intakes, Principally of Iron and Steel.
Flow of Water in Brick Conduits.
Flow of Water in Concrete Channels.
Duty of Water and Loss of Water from Canals and Reservoirs.
Rock-fill Dams.
Deterioration of Cast-Iron Pipe.
Corrosion of Steel Pipe Lines, 1903-1905.
Electrolysis of Water Mains.
Life of Cast-Iron, Cement, Wrought or Riveted-Steel Pipes.
Effect of Ice Fields upon Dams and Abutments.
"Bottom of a Dam" and "Head" of Water on a Dam: References Tending to Make Clear the Meaning of the Terms.
Experiments on the Flow of Water Over an Ogee Dam.
Backwater Due to the Construction of Fixed Dams.
Crib Dams.
Failures of Dams During the Five Years Ending October, 1906.
Rainfall in Mexico.
Water Purification; Methods and Maintenance.

WATERWAYS.

Water Supply for Canals.
Shore Protection, Wave Action, Ocean Currents, Jetties, etc.
The Elbe-Trave, Teltow, and Oder-Spree Canals.
References in Reports of Chief of Engrs., U. S. Army: locks, dams and improvements on the Ohio, Monongahela and Allegheny Rivers under Major W. L. Sibert; and on the Ohio, Kanawha and Little Kanawha Rivers in West Virginia under Major G. A. Zinn; Survey of Illinois and Desplaines Rivers, Ill., for Waterway from Lockport, Ill., to St. Louis, Mo.
Traffic, Tolls Charged, etc., in the Suez, North Sea, and Baltic Canals.
Current Meters.
Canal Lock Gates.
Canals and Canal Locks.
Hydraulic Dredges, Depositing Material on Shore through Floating Pipe Lines.
Jetty Harbors of the Baltic Sea
Hydraulic Dredges or Sand Pumps.
South Pass Jetties of the Mississippi.
Jetties and Breakwaters in Harbors.
Amount and Cost of Excavation at the "Iron Gates" of the Danube River.
Lock Gates for Tidal Harbors.
Evaporation in Natural Reservoirs.
Coal and Ore Docks in the West.
Timber Wharves Constructed in Seawater.
Chicago Main Drainage Canal, 1899-1901. References in Reports of Chief of Engrs., U. S. Army.
Breakwater at Cherbourg.
Canal Construction.
Fishways.
Atchafalaya River; Objects, Methods, Cost and Success of the Measures Taken to Sink Sills at the Entrance.
Dikes, Low and Movable Dams.

ACCESSIONS TO THE LIBRARY.

From December 6th, 1906, to January 7th, 1907.

DONATIONS.*

FOWLER'S ELECTRICAL ENGINEER'S HANDBOOK

And Directory of Light. Power and Traction Stations, 1907. Leather, 6 x 4 in., illus., 47 + 725 pp. Manchester, England, Scientific Publishing Company, 1906. 3 shillings, 6 pence net.

Owing to the growth of Electrical Engineering, it is stated that it has been necessary to add nearly 100 pages of new matter to this edition, and to rearrange the contents. The additional information consists of matter relating to electricity meters, long flame arc lamps, cable and fault testing, resistance wires, measurement of illumination, testing of alternators and transformers, designing of dynamos and motors, special types of electric lamps, as well as a number of valuable tables. The new regulations of the Board of Trade respecting overhead lines and extra high-pressure supply, as well as Lloyd's rules for electric lighting on board ship, are also given. There is an index of nineteen pages.

ATTRITION TESTS OF ROAD-MAKING STONES.

By E. J. Lovegrove; with Petrological Descriptions by John S. Flett and J. Allen Howe. Cloth, 11 x 9 in., illus., 19 + 80 pp. London, The St. Bride's Press, Ltd. 5 shillings net.

This book contains the results of tests made by the author on a large number of rocks of various classes as to their comparative values for road-making purposes. In order to make the investigations generally useful, the percentage of loss under test was considered in conjunction with petrological descriptions and photo-micrographs of the material. It is stated in the preface that the combination of the two processes assists in correcting the slight apparent errors of variation which arise in connection with attrition tests, while for quarrying variation, the test may be regarded as a reliable guide. The machine used consisted of three cast-iron cylinders, driven by a gas-engine through a counter-shaft and bevel gearing, enabling three samples of stones to be tested simultaneously. Care was taken to subject all samples to the same conditions of test, and to this end the samples were broken to a 2-in. gauge, as supplied for road work, numbering about 16 stones and weighing 4 lb. The number of revolutions recorded was confined to 8 000 and the speed to 20 rev. per min. In the wet tests the stones were weighed dry, about ½ gal. of water having been placed in the cylinder, and the weight (after testing) was ascertained when the chips and dust had been thoroughly dried again. The chips referred to in the table vary in size, and the largest piece detached from the parent stone was taken as not exceeding ½ oz. in weight. Samples of all stones referred to in the list of tests were deposited in the Museum of Practical Geology, London, England. In the descriptions of the petrological characters of road stones, only those features were noted which may be of importance in determining the durability of the stones. The Contents are: Introduction; Table of Attrition Tests; Petrological Descriptions: Granite Group; Porphyry and Porphyrite Group; Basalt and Diabase Group; Andesites; Hornfels; Quartzites and Sandstones; Limestones and Dolomites; Flint; Discussion of the Results; General Conclusions; Glossary of Technical Terms; Index to Localities; Appendix: Supplementary Table of Attrition Tests.

ELEMENTS OF GAS ENGINE DESIGN.

By Sanford A. Moss. Cloth, 6 x 4 in., illus., 2 + 197 pp. New York, D. Van Nostrand Company, 1906. 50 cents.

The preface states that this work presents, in a condensed form, the fundamental principles with which a designer of gas engines should be familiar; no attempt has been made to go into the mathematical or constructional details. Most of the work treats of the Otto cycle or four stroke cycle gas engine, and, if not stated to the contrary, each discussion is supposed to apply primarily to a single acting trunk piston engine using this cycle. Some features of other cases not common with the Otto cycle are also discussed briefly. The Contents are:

*Unless otherwise specified, books in this list have been donated by the publishers.

Chemistry and Physics of Gas Engines; Gasification of Coal; Gases not Obtained from Coal; Gas Engine Gas in General; Liquid Fuel; Discussion and Calculation of Cylinder Action; Exhaust and Admission; Compression; Combustion; Expansion and Selection of Speed; Power and Efficiency; Methods of Governing; Cylinder Action in Two Cycle Engines; Details of Design; Formulas and Constants for Gas Engine Design; Tables: Properties of Elementary Gases; Sample Gas Mixture Calculation; Properties of Gas Mixtures; Mean Effective Pressures. There is no index.

PANAMA: THE ISTHMUS AND THE CANAL.

By C. H. Forbes-Lindsay. Cloth, 7 x 5 in., illus., 368 pp. Philadelphia, The John C. Winston Co., 1906. $1 net.

The story of the Panama Canal from the earliest explorations to the present time is told in this book. Technics have been avoided as much as possible, and the subject-matter is presented in a manner interesting to the general reader. The 85-ft. level plan, upon which the Canal will be constructed, is described in detail, and illustrated with maps. For comparison a description of the counter project has been included. The Contents are: The American Isthmus under Spain; Canal Exploration; The Panama Railroad; The Isthmian Country; Colon and Panama; The Panama Canal Company; The New Panama Canal Company; The American Enterprise; The Plan of the Canal; Various Aspects of the Canal; Preparatory Work on the Isthmus. There is an appendix containing brief descriptions and statistics of operation of the great canals of the world, which matter is extracted from the monograph issued under this title by the United States Department of Commerce and Labor.

Gifts have also been received from the following:

Am. Inst. of Archts. 1 vol.
Am. Ry. Assoc. 1 pam.
Bombay Presidency-Public Works Dept. 1 pam.
Boston Soc. of Civ. Engrs. 6 pam.
Brit. Fire Prevention Comm. 1 bound vol.
Cal. Miners' Assoc. 2 pam.
Canada-Dept. of the Interior. 1 bound vol.
Clarke, D. D. 1 bound vol.
Collier, H. L. 1 bound vol.
Compagnie Universelle du Canal Maritime de Suez. 6 pam.
Cornell Univ. Library. 1 pam.
Corthell, E. L. 1 pam.
Darrach, C. G. 1 pam.
Eng. News Publishing Co. 3 bound vol.
Engrs.' Club of Cincinnati. 3 pam.
Engrs.' Soc. of Western Pennsylvania. 1 pam.
Engrs.' Soc., Univ. of Minnesota. 13 pam.
Farley, G. P. 5 bound vol., 2 vol., 1 map.
France-Ministère des Travaux Publics. 2 vol.
Granbery, J. H. 1 pam.
Great Britain-Patent Office. 8 vol., 6 pam.
Hunter, W. H. 1 pam.
Indian Midland Ry. Co., Ltd. 1 pam.
Institution of Civ. Engrs. 1 bound vol., 1 pam.
Junior Institution of Engrs. 2 bound vol.
Karapetoff, V. 1 pam.
Lea, S. H. 1 bound vol.
Lentilhon, Eugene. 1 pam.
Magruder, G. L. 1 pam.
Maryland-Geol. Survey. 1 vol.
Mass.-Board of R. R. Commrs. 1 bound vol.
Mass. Inst. of Tech. 1 vol.
Mexican Central Ry. Co., Ltd. 2 pam.
Milliken Bros. 1 bound vol.
Moore, Robert. 1 pam.
National Elec. Light Assoc. 2 vol.
National Fire Protection Assoc. 2 pam.
New England R. R. Club. 2 vol.
New York City-Board of Water Supply. 2 pam.
New York City-Dept. of Health. 3 bound vol.
New York City Record. 1 bound vol.
Ohio-Geol. Survey. 1 bound vol.
Orange River Colony-Mines Dept. 1 pam.
Philadelphia, Pa.-Bureau of Filtration. 2 pam.
Platt, T. C. 4 pam.
Pratt Inst. Free Library. 1 pam.
Providence, R. I.-City Engr. 1 pam.
Queensland, Australia-Harbours and Rivers Dept. 1 pam.
Riabouchinsky, D. 1 vol.
Rochester, N. Y.-Dept. of Public Works. 1 vol.
San Francisco, Cal.-Chamber of Commerce. 1 pam.
Southern Pacific Co. 2 pam.
Sydney Univ. Eng. Soc. 1 vol.
Tribus, L. L. 1 pam.
U. S. Bureau of Insular Affairs. 1 pam.
U. S. Bureau of Yards and Docks. 1 vol.
U. S. Coast and Geodetic Survey. 1 bound vol.
U. S. Forest Service. 3 pam.
U. S. Geol. Survey. 24 vol., 4 pam.
U. S. Isthmian Canal Comm. 2 pam.
U. S. Lake Survey Office. 2 pam.
U. S. Library and Office of Naval War Records. 11 pam.
U. S. Library of Congress. 1 bound vol.
Vermont-State Highway Commr. 1 pam.
Westinghouse Companies. 1 bound vol.

BY PURCHASE.

Ice Formation with Special Reference to Anchor-Ice and Frazil. By Howard T. Barnes. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1906.

Notes on Military Explosives. By Erasmus M. Weaver. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1906.

Anlage und Ausführung von Wasserleitungen und Wasserwerken zur Wasserversorgung von Städten, Ortschaften, Anstalten und Privatgebäuden. Leitfaden und Handbuch für Ingenieure, Architekten, Verwaltungs-Beamte und andere Berufskreise in allen Wasserversorgungsfragen. Vierte Auflage. Von Friedrich König. Leipzig, Otto Wigand, 1907.

Dynamo-Electric Machinery. A Manual for Students of Electrotechnics. By Silvanus P. Thompson. Seventh Edition (corrected). Volume I, Continuous-Current Machines; Volume II, Alternating-Current Machinery. New York, Spon & Chamberlain; London, E. & F. N. Spon, Ltd., 1905.

Abhandlungen aus dem Gebiete der Technischen Mechanik. Von Otto Mohr. Berlin, Wilhelm Ernst & Sohn, 1906.

The Engineering Index, Vol. IV; 1901-1905. Edited by Henry Harrison Suplee and J. H. Cuntz, in Co-operation with Charles Buxton Going. New York and London, The Engineering Magazine, 1906.

SUMMARY OF ACCESSIONS.

From December 6th, 1906, to January 7th, 1907.

Donations (including 14 duplicates)	172
By purchase	7
Total	179

MEMBERSHIP.

ADDITIONS.

MEMBERS.

		Date of Membership.
BAIRD, SAMUEL POND. Cons. and Contr. Engr., Portsmouth, Ohio	Assoc. M.	Mar. 1, 1899
	M.	Sept. 4, 1906
BARNES, EDWARD HARDING. Chf. Engr., G. R. & I. Ry. Co., Grand Rapids, Mich		Dec. 5, 1906
BARRALLY, THOMAS WEBSTER. 24 Young St., Tonawanda, N. Y.		Dec. 5, 1906
BROWN, ROBERT CALVIN. Box 102, Crafton, Pa		Dec. 5, 1906
BUFFINGTON, BENJAMIN THOMAS. 22 Bedford St., Fall River, Mass.	Assoc. M.	Sept. 7, 1904
	M.	Jan. 3, 1907
CARTER, SHIRLEY. Civ. Engr., U. S. Engr. Dept., Box 786, Norfolk, Va.	Jun.	May 31, 1892
	Assoc. M.	Oct. 5, 1898
	M.	Dec. 4, 1906
DOW, ALEX. 18 Washington Ave., Detroit, Mich.		Dec. 5, 1906
EDDY, HARRISON PRESCOTT. Supt. of Sewers (Res., 11 Dean St.), Worcester, Mass.	Assoc. M.	May 7, 1902
	M.	Jan. 3, 1907
FICKES, CLARK ROBINSON. Res. Engr., Shreveport Bridge & Terminal Co., Shreveport, La.		Nov. 7, 1906
GREGORY, JOHN HERBERT. Engr. in Chg., Improved Water & Sewage Works, 506 American Savings Bank Bldg, Columbus, Ohio	Jun.	Jan. 3, 1899
	Assoc. M.	April 3, 1901
	M.	Dec. 4, 1906
KNAPP, ZAC ELLIS. Asst. Engr., Underground Elec. Railways Co. of London, Ltd., 25 Hamilton House, Victoria Embankment, London, E. C., England		Dec. 5, 1906
MCCOY, SAMUEL ALEXANDER. Asst. Engr., Northern Pacific Ry., Hawley, Minn.	Assoc. M.	Sept. 6, 1905
	M.	Dec. 4, 1906
MENDIOLA, MANUEL MARIA. Ciudad Juarez, Chihuahua, Mexico		Dec. 5, 1906
PIERCE-HOPE, JOHN. Director General of Public Works, La Paz, Bolivia		Dec. 5, 1906
RALSTON, JOHN CHESTER. Min. Engr., 2421 West Mission Ave., Spokane, Wash.		Oct. 3, 1906
ROGERS, EDWIN HENRY. 8 Congress St., Boston, Mass.		Jan. 2, 1907
RYDER, ELY MORGAN TALCOTT. Engr., Consolidated Ry. Co., P. O. Box 671, Yale Station, New Haven, Conn	Jun.	Jan. 5, 1897
	M.	Dec. 5, 1906
SHAND, GADSDEN EDWARDS. 1831 Pendleton St., Columbia, S. C.		Nov. 7, 1906
TABER, GEORGE AYMAR. Asst. Engr., Aqueduct Commrs., 280 Broadway, New York City	Jun.	April 30, 1895
	Assoc. M.	June 7, 1899
	M.	Dec. 4, 1906
THIAN, PROSPER EUGENE. Chf. Engr., The Brandon, Saskatchewan & Hudson's Bay Ry. Co., Box 367, Brandon, Man., Canada		Nov. 7, 1906

MEMBERS (*Continued*).

	Date of Membership.
WELLS, LAWRENCE WILLIAM. Chf. Engr., Tex. Midland R. R., Terrell, Tex	Dec. 5, 1906

ASSOCIATE MEMBERS.

ALEXANDER, ROBERT LEE. Res. Engr., Northern Pacific Ry., St. Regis, Minn..	Jun.	Nov. 1, 1904
	Assoc. M.	Dec. 5, 1906
BILLINGS, ASA WHITE KENNEY. Cons. Engr., Empedrado No. 30, Havana, Cuba		Dec. 5, 1906
BIRKS, ARTHUR HENRY. With Phœnix Bridge Co., Phœnixville, Pa	Jun.	April 5, 1904
	Assoc. M.	Nov. 7, 1906
BISSELL, CLINTON TALCOTT. Res. Engr., Brighton Beach Impvt., Brooklyn Heights R. R., 315 Lafayette Ave., Brooklyn, N. Y		Dec. 5, 1906
BUTTERFIELD, HERBERT MITCHELL. Care, W. Palliser, Kampong Bahree, Singapore, Straits Settlements		Oct. 3, 1906
DECKER, JOHN HULL. Chf. Engr. and Gen. Mgr., Atlantic Constr. & Supply Co., 232 Bartlett Bldg., Atlantic City, N. J...	Jun.	Sept. 6, 1904
	Assoc. M.	Dec. 5, 1906
DE GRATRESSE, JOSEPH REYGONDEAU, 2140 South Broad St., Philadelphia, Pa		Jan. 2, 1907
DIAMANT, ARTHUR HERBERT. Asst. Engr. in Chg. of Aqueduct Div., Aqueduct Commrs., Res., 531 West 124th St., New York City	Jun.	May 5, 1903
	Assoc. M.	Dec. 5, 1906
DUIS, FREDERICK BERNHARDT. U. S. Engr. Office, Wheeling, W. Va		Dec. 5, 1906
EDWARDS, OLIVER CROMWELL, JR. Pres., American Concrete Caisson Co., National State Bank Bldg. (Res., 2105 Fifteenth St.), Troy, N. Y	Jun.	Oct. 7, 1902
	Assoc. M.	Dec. 5, 1906
FRENCH, GEORGE HARRISON. U. S. Asst. Engr., Fullerton Bldg., St. Louis, Mo		Dec. 5, 1906
GILMAN, CHARLES EDWARD. Asst. Engr., Bay Cities Water Co., 1368 Geary St., San Francisco (Res., 430 Forest Ave., Palo Alto), Cal	Jun.	Oct. 6, 1903
	Assoc. M.	Dec. 5, 1906
HARTMAN, ALFRED HANSON. Asst. Engr., Baltimore Sewerage Comm., 807 American Bldg., Baltimore, Md	Jun.	Dec. 6, 1904
	Assoc. M.	Dec. 5, 1906
HAYLOW, JAMES HENRY. 172 Walnut St., Memphis, Tenn.		Dec. 5, 1906
HILTON, JOSEPH CHURCHILL. 47 Pierrepont St., Brooklyn, N. Y		Jan. 2, 1907
HURLBUT, CHARLES CHASE. 320 Fifth Ave., New York City		Dec. 5, 1906
JENKINS, JAMES EDGAR. With Penn., N. Y. & L. I. R. R., 1 West 34th St., New York City		Dec. 5, 1906

ASSOCIATE MEMBERS *(Continued)*.

		Date of Membership.
LEE, AUGUSTINE LEFTWICH. Asst. Engr., Am. Bridge Co., Ambridge, Pa.		Oct. 3, 1906
MINNISS, GEORGE STEWART. 702 Ellicott Sq., Buffalo, N.Y.		Dec. 5, 1906
RANDOLPH, JOHN HAMPDEN, JR., 1102 Florida St., Baton Rouge, La.		Dec. 5, 1906
RICHARDSON, JAMES HERBERT. Care, Am. Bridge Co., 42 Broadway, New York City.		Jan. 2, 1907
SCHODER, ERNEST WILLIAM. Asst. Prof. of Experimental Hydraulics and Engr. in Chg. of Hydr. Laboratory, Cornell Univ., 410 E. Yates St., Ithaca, N. Y.	Jun. Assoc. M.	Oct. 1, 1901 Jan. 2, 1907
SCOTT, ALBERT LYON. 93 Federal St., Boston, Mass.		Nov. 7, 1906
SEASTONE, CHARLES VICTOR. Anna, Ill.		Dec. 5, 1906
SEYFERT, EDGAR ERNEST. 1229 So. 47th St., Philadelphia, Pa.		July 9, 1906
SHRYOCK, JOSEPH GRUNDY. Designing Engr., Belmont Iron Works, 1622 Real Estate Trust Bldg., Philadelphia, Pa.	Jun. Assoc. M.	April 2, 1901 Dec. 5, 1906
SNELL, HARRY BRONSON. Prin. Asst. Engr., Brighton Beach Impvt., Brooklyn Heights R. R., 44 Court St., Brooklyn, N. Y.		Dec. 5, 1906
SOPER, ELLIS CLARK. South Pittsburgh, Tenn.		Dec. 5, 1906
SUDRIERS, VICTOR BOUREAU. Orillas del Plata, 126a Montevideo, Uruguay.		Oct. 3, 1906
SUTER, RUSSELL. Asst. Engr., Board of Water Supply, 299 Broadway, New York City.		Jan. 2, 1907
TAYLOR, NORMAN ALFRED. Asst. Engr., Dept., State Engr. and Surv., State Hall, Albany (Res., 603 Grand St., Troy), N.Y.	Jun. Assoc. M.	Oct. 6, 1903 Dec. 5, 1906
WADSWORTH, GEORGE REED. With Constr. Dept., J. G. White & Co., Inc., 43 Exchange Pl., New York City.		Nov. 7, 1906
WARREN, HERBERT ANSON. Contr. Mgr., Am. Bridge Co. of N. Y., 42 Broadway, New York City.		Sept. 5, 1906
WHITSON, ABRAHAM UNDERHILL. Eastport, N. Y.	Jun. Assoc. M.	Jan. 7, 1902 Dec. 5, 1906

ASSOCIATES.

BROOKS, DAVID WALKER. Clinton Bldg., Columbus, Ohio.		Dec. 5, 1906

JUNIORS.

BALDRIDGE, JAMES RAMSEY. 840 West End Ave., New York City.		Dec. 4, 1906
BATES, LINDON, JR. 111 Broadway, New York City.		Jan. 3, 1907
DUNCAN, JAMES HARPER. Houlton, Me.		Dec. 4, 1906
EARLE, FRANK HASBROUCK, JR. 163 North 7th St., Newark, N. J.		Dec. 4, 1906

JUNIORS (*Continued*).		Date of Membership.
FERTIG, JEROME HENRY. Asst. Engr., U. S. Reclamation Service, Montrose, Colo.		Oct. 2, 1906
HARRISON, RUSSELL EDWIN. 613 The Nasby, Toledo, Ohio.		Oct. 30, 1906
KETCHUM, MORRIS. 149 East 62d St., New York City.		Dec. 4, 1906
MALCOLM, CHARLES WESLEY. 412 E. Green St., Champaign, Ill.		Sept. 4, 1906
MERCER, CHARLES DOUGLAS. 31 Milk St., Boston, Mass.		Sept. 4, 1906
QUERBACH, EARL. 316 Thorn St., Sewickley, Pa.		Dec. 4, 1906
ROBERTS, HARRY ASHTON. Div. Engr., Montana Div., Ore. Short Line R. R., Pocatello, Idaho	Jun. Assoc. M.	April 5, 1904 Dec. 5, 1906
STIRLING, VINCENT REYNOLDS. Care, Bureau of Lands, Manila, Philippine Islands		Oct. 2, 1906
TOWLE, FOSTER. Care, Board of Water Supply, High Falls, N. Y.		Oct. 30, 1906
WILSON, WILLIAM WEST. 840 West End Ave., New York City.		Dec. 4, 1906

RESIGNATIONS.

MEMBERS.	Date of Resgnation.
CAMPBELL, HARRY HUSE	Dec. 4, 1906
ECKERT, EDWARD WILLIAM	Jan. 3, 1907
KEENE, WILLIAM FAITOUTE	Jan. 3, 1907
KENLY, WILLIAM WATKINS	Jan. 3, 1907
ASSOCIATE MEMBERS.	
MOSES, PERCIVAL ROBERT	Dec. 4, 1906
WOODRUFF, JAMES ALBERT	Jan. 3, 1907
ASSOCIATES.	
ABBOTT, WILLIAM LATHAM	Jan. 3, 1907
JUNIORS.	
IRELAND, MARK LORIN	Jan. 3, 1907

DEATHS.

BROWN, ALBA FISK. Elected Member, September 7th, 1887; died April 22d, 1906.

JOHNSON, WALLACE CLYDE. Elected Member, October 5th, 1892; died December 15th, 1906.

KENYON, GEORGE CECIL. Elected Associate Member, April 4th, 1900; Member, June 6th, 1905; died October 30th, 1906.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(December 6th, 1906, to January 5th, 1907.)

NOTE.—*This list is published for the purpose of placing before the members of the Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles, references are given by the number prefixed to each journal in this list.

(1) *Journal*, Assoc. Eng. Soc., 31 Milk St., Boston, Mass., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City. Issues for first Saturday of each month, 20c., other issues 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l'Assoc. des Ing. Sortis des Ecoles Speciales de Gand*, Brussels, Belgium.
(32) *Memoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Genie Civil*, Paris, France.
(34) *Portefcuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(37) *Revue de Mecanique*, Paris, France.
(38) *Revue Generale des Chemins de Fer et des Tramways*, Paris, France.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussees*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.

(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 803 Fulton Bldg., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne, England.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Industrial World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(70) *Engineering Review*, New York City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.
(72) *Electric Railway Review*, Chicago, Ill., 30c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, Ill., 10c.
(77) *Journal*, Inst. Elec. Engrs., London, England.
(78) *Beton und Eisen*, Vienna, Austria.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie-Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Dinglers Polytechnisches Journal*, Berlin, Germany.
(83) *Progressive Age*, New York City, 15c.
(84) *Le Ciment*, Paris, France.
(85) *Proceedings*, Am. Rv. Eng. and M. of W. Assoc., Chicago, Ill.
(86) *Engineering World*, Chicago, Ill.

LIST OF ARTICLES.

Bridge.

Report of Committee on Iron and Steel Structures (with Specifications).* (85) Vol. 7.
A System of Uniform Live Loads for Railroad Bridges, and a Formula for Shearing Stress in Webs and Spacing of Stiffeners of Plate Girders.* A. W. Buel. (85) Vol. 7.
Report of Committee on Wooden Bridges and Trestles (with Specifications). (85) Vol. 7.
Some Bridge Failures During a Heavy Cyclone in 1905 in Gujerat, India.* Andrew Thomas, Assoc. M. Inst. C. E. (63) Vol. 166.
Bridges and Viaducts on the Guatemala Ry.* (14) Dec. 8.
The North Platte River Bridge of the Union Pacific.* (15) Dec. 14.
Notes on the Fabrication of the Quebec Bridge. (14) Dec. 15.
Adjustable Connection of Anchor-Arm Lateral System, Quebec Bridge.* (14) Dec. 29.
Progrès dans la Construction des Grandes Voûtes Surbaissées. (From *Zentralblatt der Bauverwaltung.*) (30) Dec.
Zur Frage der Kalibrierung Breitflanschiger I-Träger.* C. Holzweiler. (50) Dec. 1.

Electrical.

Analysis of Alternating Current Waves. L. A. Hazeltine. (8) Oct.
A New Type of Continuous-Current Dynamo Electric Machine with Commutating Poles.* V. A. Fynn. (73) Nov. 30.
The Physical Meaning of Power Factor and the Significance of a Power Factor Less than Unity without Phase Difference.* Albert F. Ganz. (3) Dec.
Static Balancers for 3-Wire Distribution Systems.* (47) Dec. 1.
The New Incandescent Electric Lamps. (12) Serial beginning Dec. 7.
The Snowdon Hydro-Electric Installation of the North Wales Power and Traction Co., Ltd.* (26) Dec. 7.
The Single-Phase Induction Motor.* Alfred Still. (27) Serial beginning Dec. 8.
Experiments on Carbon, Osmium and Tantalum Lamps.* J. T. Morris. (73) Dec. 14.
The Third Function of Electric Traction Motors.* Edward H. Johnson. (Abstract of paper read before the Manchester Assoc. of Engrs.) (73) Dec. 14.
Radiotelegraphy and the Telefunken System.* (11) Serial beginning Dec. 14.
Recent Practice in Electrical Transmission of Power.* W. B. Esson, M. Inst. C. E. (12) Dec. 14.

*Illustrated.

Electrical—(Continued).

The Siemens-Schuckert Single-Phase Series Motor.* Rudolf Richter. (26) Dec. 14.
The Hydro-Electric Plant of the Belton Power Company.* George Wrigley. (27) Dec. 15; (14) Dec. 15.
Tests of Incandescent Lamps.* L. B. Spinney. (27) Dec. 15.
The Poulsen Selective System of Wireless Telegraphy.* A. Frederick Collins. (46) Dec. 15.
How to Construct an Independent Interrupter.* A. Frederick Collins. (46) Dec. 15.
A New Swedish Electrical Combine and its Products.* (26) Dec. 21.
Recent Advances in the Construction of Constant Current Dynamos.* E. Rosenberg. (Abstract from *Elektrotechnische Zeitschrift.*) (73) Dec. 21.
Hydro-Electric Developments at Huntingdon, Pa. (27) Dec. 22.
The Design of Induction Coils.* Wm. O. Eddy and Melville Eastham. (27) Dec. 22.
The New Power Plant for Railway and Lighting Service in Waltham.* (17) Dec. 29.
Single-Phase Light and Power Plant at Belleville, Ill.* (27) Dec. 29.
On an Approximate Measurement, by Electrolytic Means, of the Electrostatic Capacity between a Vertical Metallic Cylinder and the Ground.* A. E. Kennelly and S. E. Whiting. (27) Dec. 29.
Small Central Station Problem.* Harry V. Forest. (Abstract of paper read before the Kansas Gas, Water and Elec. Assoc.) (27) Dec. 29.
Long-Distance Power Transmission with Direct Currents.* C. T. Wilkinson. (10) Jan.
Die Gefahrquellen in Elektrischen Wechselstromanlagen und Einige Moderne Schutzvorrichtungen zur Abwendung der Gefahren. Hermann Zipp. (48) Nov. 24.

Marine.

The Western River Steamboat.* A. H. Blaisdell. (Paper read before the Engrs. Club of St. Louis.) (1) Oct.
The Proposed Channel Ferry Service.* (11) Dec. 7.
The Submarines and Submersibles of France.* (12) Dec. 21.
The Clark Freight Unloader.* (20) Dec. 27.
A Fireproof Ferry-Boat.* F. L. DuBosque, M. Soc. N. A. and M. E. (Paper read before the Soc. of Naval Archts. and Marine Engrs.) (13) Dec. 27.
Construction of a Fireproof Excursion Steamer.* William Gatewood, M. Soc. N. A. and M. E. (Paper read before the Soc. of Naval Archts. and Marine Engrs.) (13) Dec. 27.
The Stability of Submarines.* W. H. Stuart Garnett. (10) Jan.
Les Nouveaux Cuirassés de la Marine Française.* L. Piaud. (33) Dec. 1.
Projet d'un Service de Ferry-Boats entre la France et l'Angleterre.* (33) Dec. 22.
Hochdruckdampfrohrleitung im Schiffsbetriebe.* Uthemann. (48) Nov. 24.
Versuche mit dem Schiffskreisel. O. Schlick. (48) Serial beginning Dec. 1.

Mechanical.

Some Notes on High Versus Low Grade Gas.* Edward Allen. (Paper read before the Manchester District Inst. of Gas Engrs.) (66) Nov. 27.
A New Apparatus for Preparing Lime for Gas Purification.* S. Glover. (Paper read before the Manchester District Inst. of Gas Engrs.) (66) Nov. 27.
The Development and Present Status of the Steam Turbine in Land and Marine Work.* E. M. Speakman. (Abstract of paper read before the Inst. of Engrs. and Shipbuilders in Scotland.) (11) Nov. 30.
The Strength of Coil Springs. H. E. Wimperis. (12) Nov. 30.
New Rail Mill of Dominion Iron and Steel Company, Limited, Sydney, Cape Breton.* (22) Nov. 30.
A 100 000-Kilowatt Steam-Turbine Station.* J. C. Thorpe. (64) Dec.
Actual Turbine Results.* (64) Dec.
The Hydraulic Elevator.* Wm. Baxter, Jr. (64) Dec.
Characteristics of Some Power Gases and Their Treatment. L. L. Brewer. (64) Dec.
Condensers for Steam Engines and Turbines.* Frank Foster. (Abstract of paper read before the Owens College Eng. Soc.) (64) Dec.
Direct Leakage of Steam Through Slide Valves. J. V. Stanford. (3) Dec.
Modernization at Tamworth.* (Gasworks.) (66) Dec. 4.
Benzolized Water Gas. A. O. Jones. (Paper read before the Midland Junior Gas Assoc.) (66) Dec. 4.
The Parsons Steam Turbine.* John D. Baille. (Paper read before the Birmingham Assoc. of Mech. Engrs.) (22) Serial beginning Dec. 7.
Steam Traps.* W. H. Wakeman. (19) Dec. 8.
Gas Turbines.* Frank Foster. (47) Serial beginning Dec. 8.

*Illustrated.

Mechanical—(Continued).

On the Manufacture of Oil Gas. H. Leicester Greville. (66) Dec. 11.
The Treatment of Blast-Furnace Gases. John Gillespie. (Abstract of paper read before the Scottish Junior Gas Assoc.) (66) Dec. 11.
The Trials of Suction Gas Plants at Derby, 1906. (12) Serial beginning Dec. 14; (66) Dec. 25.
Gas as a Source of Power. Willard L. Case. (19) Serial beginning Dec. 15.
Large Gas Engines for Power Purposes.* J. E. Aue. (Paper read before the Pacific Coast Gas Assoc.) (83) Dec. 15.
A New Method of Rolling Round Bars.* (20) Dec. 20.
The Wallace Alcohol Calorimeter.* (12) Dec. 21.
Greater Economy Needed in the Production of Compressed Air. (19) Dec. 22.
The "Ados" Automatic Co. Recorder for Boiler Furnaces.* (19) Dec. 22.
Dirigible Airships.* Count von Zeppelin. (19) Dec. 22.
Loam Moulding. E. L. Rhead. (47) Serial beginning Dec. 22.
Incandescent Mantles made from Artificial Silk.* C. Richard Böhm. (66) Dec. 25.
Lighting and Maintenance (Gaslight).* L. F. Tooth. (Abstract of paper read before the London and Southern Junior Assoc.) (66) Dec. 25.
The Clark Freight Unloader.* (20) Dec. 27.
Pistons for Internal Combustion Engines.* H. S. Brown. (20) Dec. 27.
Cost of Steam Shovel Work. (14) Dec. 29.
Suction Gas Engines and Gas Plants. Hugh Campbell. (62) Serial beginning Dec. 29.
Operating Experience with Four-Stage Curtis Turbines. C. E. Stanton. (Abstract of paper read before the Iowa Electrical Assoc.) (14) Dec. 29.
Description of a Cold Storage Plant Utilizing Exhaust Steam.* Henry Torrance, Jr. (Paper read before the Amer. Soc. of Refrigerating Engrs.) (14) Dec. 29.
The Gas Turbine.* René Armengaud. (10) Jan.
Modern Machine Shop Requirements.* Joseph Horner. (10) Jan.
Extinguishing the Flame of a 600-Pound Pressure, Million-Feet Hourly Capacity, Natural Gas Well.* W. M. Welch. (Paper read before the Amer. Gas Inst.) (83) Jan. 1.
The Standardization of Incandescent Gas Mantles.* Van Rensselaer Lansingh. (Paper read before the Amer. Gas Inst.) (83) Jan. 1; (24) Dec. 31.
The Lackawanna Steel Company.* (20) Jan. 3.
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AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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THE DESIGN OF THE NEW CROTON DAM.

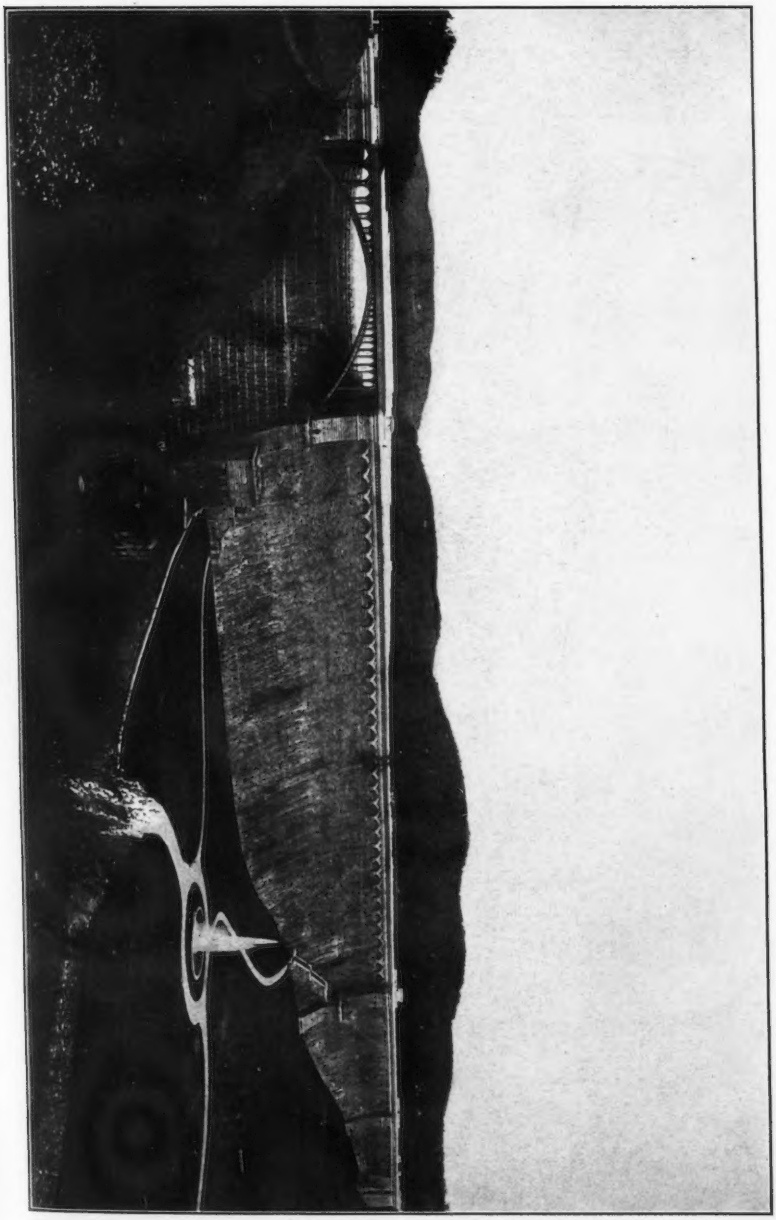
By Edward Wegmann, M. Am. Soc. C. E.

To be Presented February 20th, 1907.

The New Croton Reservoir was constructed in 1892-1906 to store an additional supply of water from the Croton watershed for the City of New York. An aqueduct 33.12 miles long, having a capacity of about 300 000 000 gal. per day, was built to convey the water from this reservoir to the city.

The reservoir was formed by constructing a high masonry dam (Plate I) across the Croton River, about 6 miles above its mouth. According to the original plans, the dam was to be built across the Croton River a short distance above the old "Quaker Bridge," the proposed structure being called the Quaker Bridge Dam. Owing to the great opposition to this project that arose at the "public hearings" held for a discussion of the proposed plans, the Aqueduct Commissioners of the City of New York, who had charge of the construction of the new reservoir and aqueduct, decided to build the dam about 1¼ miles farther up stream, on lands belonging to A. P. Cornell and others. For this reason the dam was first called the "Cornell Dam," but this name was soon changed to "The New

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.



THE NEW CROTON DAM.

Croton Dam," as an older dam, built 3¼ miles farther up stream in 1837-1842, was known as the Old Croton Dam.

The plans for the New Croton Dam were prepared under the direction of the late Alphonse Fteley, Past-President, Am. Soc. C. E., Chief Engineer of the Aqueduct Commissioners, who had charge of the construction of the work to January 1st, 1900, when he resigned on account of ill health. He was succeeded as Chief Engineer by the following gentlemen, all of whom are Members of the American Society of Civil Engineers: William R. Hill, January 1st, 1900, to October 14th, 1903; J. Waldo Smith, October 15th, 1903, to August 1st, 1905; Walter H. Sears, August 1st, 1905, to date.

Charles S. Gowen, M. Am. Soc. C. E., was in immediate charge of the construction of the dam as Division Engineer, from the beginning to August 31st, 1905, when he resigned and was succeeded by Mr. F. B. Rogers.

The contract for constructing the dam was awarded on August 26th, 1892, to James S. Coleman, the lowest bidder, for $4 150 573. Mr. Coleman assigned his contract, on January 2d, 1895, to the firm of Coleman, Ryan and Brown, who, on July 13th, 1898, assigned the contract to Coleman, Breuchaud and Coleman. The original contractor was the senior member of both these firms. Ground was broken for the construction of the dam on September 20th, 1892, and the work was practically completed by February 1st, 1906, at a cost of $7 631 185.69,* the increase in cost above the original bid being principally due to a number of changes in the plans for the dam.

According to the contract plans, the dam was to consist of:

First.—A masonry waste-weir, about 1 000 ft. long, along the rocky side-hill forming the north slope of the valley;

Second.—A masonry dam about 600 ft. long, extending from the waste-weir, almost at right angles thereto, across the valley, and well into the south slope; and,

Third.—An earthen dam with masonry core-wall, about 600 ft. long, forming a continuation of the masonry dam to the south side of the valley.

*This amount includes, besides the cost of the masonry dam, the expense of constructing about 20 miles of new highways and of reinforcing about 3 miles of the old aqueduct submerged by the new reservoir.

The plans were modified subsequently by building the whole dam of masonry with the exception of a length of 145 ft. at the south end, which was made an earthen dam with a masonry core-wall, according to the original plans. The maximum height of this earthen dam above the surface of the ground is only about 26 ft.

The general plans for the dam and the construction of the foundations have been fully described by Mr. Gowen.* The principal changes made in the plans have also been discussed by Mr. Gowen.† These changes consisted in the substitution of a masonry structure for the proposed earthen dam. An account of how the dam was built may be found in Mr. Gowen's papers; the writer will consider herein only the design adopted for the dam.

The Design of the Dam.—Extensive studies and calculations were made in designing the proposed Quaker Bridge Dam. The profile and plan adopted for the New Croton Dam were based entirely upon the plans prepared for the Quaker Bridge Dam. Therefore the writer will explain fully how the latter was designed.

The first plans for the Quaker Bridge Dam were prepared by the engineers of the Department of Public Works of the City of New York, under the direction of the Chief Engineer, the late Isaac Newton, M. Am. Soc. C. E., who was assisted by the late E. S. Chesbrough, M. Am. Soc. C. E., the late J. W. Adams, Past-President, Am. Soc. C. E., and Mr. B. S. Church, as Consulting Engineers. In this connection Mr. Chesbrough inspected the principal high masonry dams in Europe, but, unfortunately, he died before he could write his report on the subject.

The profile designed by the engineers of the Department of Public Works is shown in Fig. 1. No report is on record explaining why this form was adopted, but, from statements made by the engineers who assisted in preparing the plans, it appears that the profile was determined by a graphic method given by A. de Beauve in his "Manuel de l'Ingénieur des Ponts et Chaussées,"‡ a limiting pressure of 100 lb. per sq. in. being assumed for both the up-stream and the down-stream faces of the dam to the river-bed. Below the river-bed, both faces were made vertical. The maximum pressure

* *Transactions*, Am. Soc. C. E., Vol. XLIII. p. 469.

† *Transactions*, Am. Soc. C. E., Vol. LVI, p. 32.

‡ A translation of that part of the "Manuel de l'Ingénieur" which gives the graphic method was made for the Department of Public Works by the late E. Sherman Gould, M. Am. Soc. C. E.

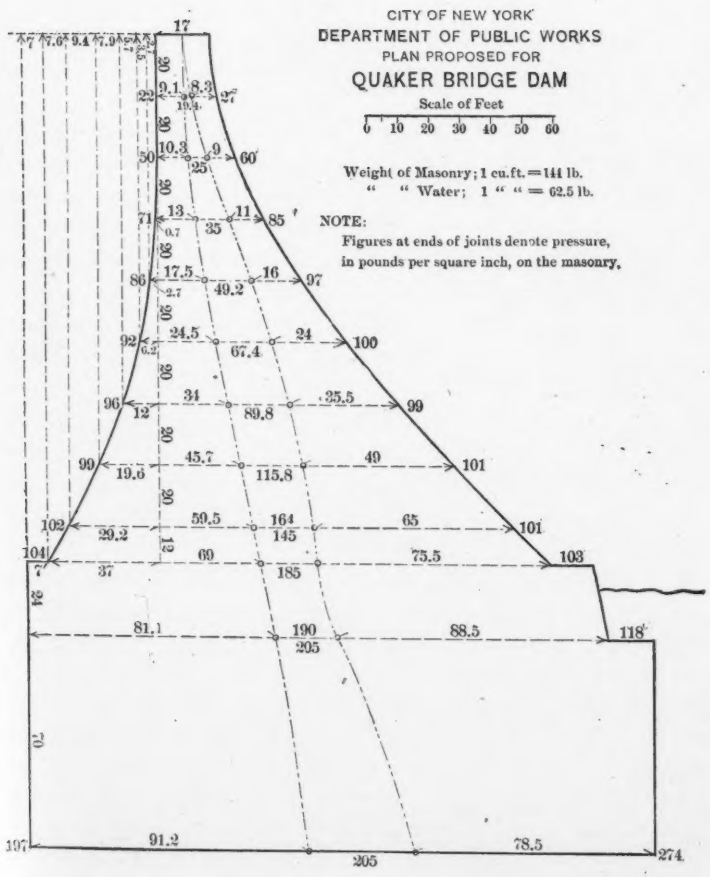

CITY OF NEW YORK
DEPARTMENT OF PUBLIC WORKS
PLAN PROPOSED FOR
QUAKER BRIDGE DAM
Scale of Feet
0 10 20 30 40 50 60
Weight of Masonry; 1 cu. ft. = 144 lb.
" " Water; 1 " " = 62.5 lb.
NOTE:
Figures at ends of joints denote pressure, in pounds per square inch, on the masonry.
17
27
60
85
97
100
99
101
101
103
118
274
205
91.2
78.5
88.5
81.1
190
205
69
75.5
185
37
50.5
164
65
145
29.2
45.7
49
115.8
19.6
34
35.5
89.8
12
24.5
24
67.4
17.5
16
49.2
2.7
13
11
35
0.7
10.3
9
25
9.1
8.3
19.4
22
30
20
12
24
92
102
104
96
99
86
71
50
22
197

FIG. 1.

at the foundation was calculated to be 274 lb. per sq. in. at the down-stream face, and 197 lb. per sq. in. at the up-stream face.

The reason which induced the engineers to make both faces of the dam vertical below the river-bed is not apparent; nor is it clear why they were willing to subject the masonry at the down-stream face of the foundation to a pressure of nearly 20 tons per sq. ft. The following explanations of these points have been made unofficially by some of the engineers who assisted Mr. Isaac Newton in making the designs:

1.—It was assumed that below the river-bed the water pressures against the up-stream and down-stream faces of the dam balanced each other. This view is evidently incorrect, as the water pressure on the down-stream face (assuming the river-bed to be saturated with water) would only be equal to the increase in water pressure on the up-stream face below the river-bed.

2.—The masonry below the river-bed, being supported laterally by the back-filling, could support safely much greater pressures than the masonry above the river-bed. Although this statement is probably correct, it would be impossible, in the present state of knowledge, to estimate how much additional strength would result from this support. It was also stated that the friction between the masonry below the river-bed and the back-filling would relieve part of the pressure on the masonry.

The plans for the Quaker Bridge Dam, received from the Department of Public Works, were referred by the Aqueduct Commissioners to their own Engineer Department, at the head of which they had placed Mr. B. S. Church as Chief Engineer, Mr. A. Fteley as Deputy Chief Engineer, and Joseph P. Davis, M. Am. Soc. C. E., as Consulting Engineer. These engineers made a very thorough investigation of the subject of high masonry dams. The mathematical part of the studies was assigned to the writer, who, at the time, was Assistant Engineer of Construction in the service of the Aqueduct Commissioners.

At that time (1884) there was only one high masonry dam in the United States, the Boyd's Corners Dam, 78 ft. high, constructed in 1866 to 1872, in Putnam County, N. Y. Several high masonry dams had been built or were under construction in France, notably the Furens Dam, 164 ft. high, built in 1862 to 1866, near St.

Etienne. Very little had been published about high masonry dams in English engineering literature, but a number of articles on this subject had appeared in the *Annales des Ponts et Chaussées.* The first search made by the engineers of the Aqueduct Commission was for methods of proportioning the profile of a masonry dam, and the following were found:

1.—De Sazilly's method, in his memoirs on "A Type of Profile of Equal Resistance for Reservoir Walls." (*Annales des Ponts et Chaussées,* 1852.)

2.—Delocre's method, in his memoir on the form of profile to be adopted for high reservoir walls. (*Annales des Ponts et Chaussées,* 1866.)

3.—Professor W. J. M. Rankine's method, in his "Report on the Design and Construction of Masonry Dams," (*The Engineer,* January 5th, 1872.)

4.—Bouvier's formulas, in his memoir on "Calculations of Resistance of High Masonry Dams." (*Annales des Ponts et Chaussées,* 1875.)

5.—Pelletreau's method, in his memoirs on "Walls which Sustain the Pressure of Water." (*Annales des Ponts et Chaussées,* 1876 and 1877.)

6.—De Beauve's graphic method, given in his "Manuel de l'Ingénieur des Ponts et Chaussées." (Paris, 1878.)

The methods mentioned, with the exception of some minor variations, are all based on the principles first pointed out by De Sazilly. Prior to the appearance of his memoir, masonry dams had not been designed according to scientific principles. In fact, it has been shown that some of the dams built would be stronger if their positions were reversed, the up-stream face being turned down stream. De Sazilly stated that, in order to be safe, a masonry dam must comply with the following two conditions:

a.—The pressures on the masonry or on the foundation must not exceed certain safe limits; and

b.—There must be an ample margin of safety against the dam sliding on its foundation, or shearing apart.

He was unable to devise a formula satisfying these two conditions, but found that if a profile were designed to satisfy the first condition, the pressure on the masonry and the foundations being limited to from 8 000 to 12 000 lb. per sq. ft., there would be no possibility of the dam sliding or shearing apart. If a dam should be designed to sustain greater pressures on the masonry and foundation, and if it were found, on trial, that it did not have sufficient resistance to sliding or shearing, De Sazilly recommended that the profile be recalculated with a lower limit of safe pressure, until a profile was obtained that satisfied both the above-mentioned conditions.

Resolving the inclined resultant of the water pressure and the weight of the masonry into horizontal and vertical components, De Sazilly considered the former component to be resisted at the base of the dam by the friction between the base and the foundation, and by the adhesion of the masonry to the foundation. He assumed the vertical component to be distributed on the base of the dam as a uniformly varying pressure. This distribution can be represented graphically by plane figures, the centers of gravity of which lie in the line of action of the vertical component. Four cases may arise:

I.—When the vertical component intersects the base of the dam at its center, the distribution of pressure is shown by a rectangle, the area of which represents the total pressure.

II.—When the vertical component intersects the base between its center and the limit of its center-third, the distribution of pressure is shown by a trapezoid.

III.—When the component intersects the base just at the limit of its center-third, the trapezoid of distribution becomes a triangle.

IV.—When the line of action of the vertical component crosses the base between the limit of its center-third and the nearer extremity of the base, the distribution is shown by two triangles, one representing a negative strain, or tension, and the other a positive strain, or compression.

Formulas can readily be derived by calculating the maximum pressures resulting from the above-mentioned distribution of pressure.* For the trapezoid diagram, which changes from a rectangle

* "The Design and Construction of Dams," by Edward Wegmann, M. Am. Soc. C. E., p. 10.

to a triangle as the line of action of the vertical component moves from the center of the base to the limit of its center-third it will be found that:

$$p = \frac{2\,W}{l}\left(2 - \frac{3\,u}{l}\right) \ldots\ldots\ldots\

mentioned formulas, the pressures at the faces of the dam being less, and those near the center of the dam greater, than the values calculated by these formulas. While this statement is probably correct, no rational formula, taking the elasticity of the masonry into account, has yet been proposed. As it is probable that Formulas A, B and C exaggerate the amount of pressure near the faces of the dam, where the masonry is weakest, they are evidently safe.

De Sazilly calculated the resistance of a dam to sliding or shearing, in the following manner:

In Fig. 2:

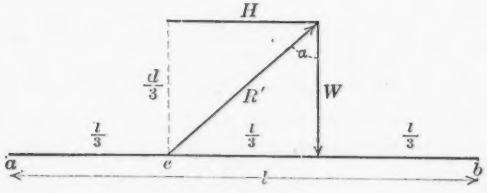


FIG. 2.

Let H = the horizontal thrust of the water;
d = the depth of the water;
l = the length of the base of the dam, $a\ b$;
W = the total vertical pressure on the base;
R = the resultant of H and W;
f = the coefficient of friction;
e = the adhesion of the base to its foundation per unit of length;
i = the angle made by R with a vertical line.

The dam cannot slide on its foundation without overcoming the friction which would result from this motion and, also, the adhesion of the base of the dam to the foundation.

Equilibrium is assured when

$$H \leqq f\,W + e\,l \qquad \text{(D)}$$

This formula may be applied to any assumed horizontal joint above the base; in which case e will represent the cohesion of the masonry. The value of f, as taken by different writers, has varied from 0.67 to 0.75; the value of e, while considerable, has not yet

been determined. De Sazilly recommended neglecting $e\ l$, as an additional margin of safety, and writing:

$$H \begin{matrix} = \\ < \end{matrix} f\ W \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (E)$$

whence,

$$f \begin{matrix} = \\ > \end{matrix} \frac{H}{W} = \text{tan. } i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (F)$$

which gives the least value of f which will prevent sliding. Formula E can be used for calculating the resistance of the dam to shearing at any assumed horizontal joint; in which case f represents the resistance to shearing.

The foregoing method of determining the resistance of the dam to sliding or shearing has been followed thus far by all writers on the subject.

De Sazilly stated that, in making calculations for determining the profile of a dam, two extreme cases should be considered, namely, reservoir full and reservoir empty. In the first case the pressures at the down-stream face of the dam reach their greatest intensity, while in the second case the pressures at the up-stream face reach their greatest values. To obtain the most economical profile for a dam, the design should be made so that the maximum pressures at both faces are equal to the adopted limit of safe pressure. De Sazilly called this type a profile of equal resistance. He obtained differential equations for determining the faces of such a profile, but was unable to integrate them. Close approximations to the theoretical profile of minimum area may be obtained by substituting for curved faces either polygonal outlines or steps. De Sazilly adopted the latter alternative, and designed a stepped profile, Fig. 3, for which he devised equations of the fourth degree.

The next writer on the subject, M. Delocre, who made the theoretical studies for the Furens Dam, in France, the highest dam in Europe, adopted all the principles laid down by De Sazilly, but gave the profile of the dam polygonal outlines, Fig. 3, as the steps proposed by De Sazilly involve a waste of masonry and an additional expense in cutting them. Delocre's method is quite laborious, and involves the solution of equations of the sixth degree.

About 1871, Professor W. J. M. Rankine was requested, in connection with some proposed reservoirs for Bombay, India, to make a mathematical investigation of the best form of profile for a

masonry dam. Rankine adopted the same general principles as De Sazilly and Delocre, but stated that, in addition to limiting the pressures in the masonry, it was important to keep the lines of pressure, reservoir full or empty, within the center-third of the profile, in order to avoid tension in the masonry.

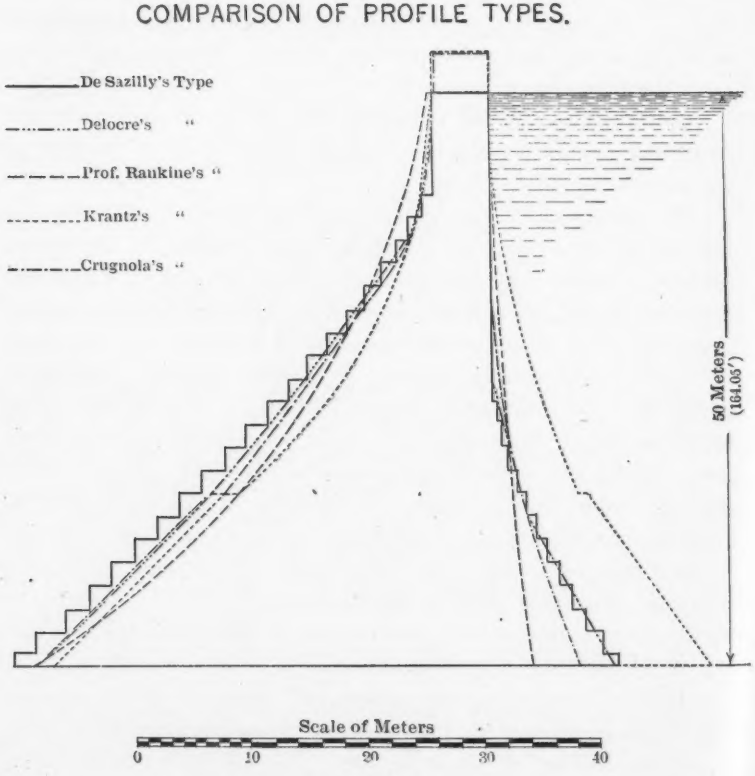


FIG. 3.

In calculating the maximum pressures in the masonry, the French engineers assumed the same limit of safe pressure for the up-stream and down-stream faces, and, for the case of "reservoir full," they only considered the vertical component of the weight of the masonry and of the horizontal thrust of the water, in calcu-

lating the distribution of pressure at any assumed horizontal joint. Rankine, however, states in his report:

"It appears to me that there are the following reasons for adopting a lower limit at the down-stream than at the up-stream face. The direction in which the pressure is exerted among the particles close to either face of the masonry is necessarily that of a tangent to that face; and, unless the face be vertical, the pressure found by means of the ordinary formulæ is not the whole pressure, but only its vertical component; and the whole pressure exceeds the vertical pressure in a ratio which becomes the greater, the greater the 'batter' or deviation of the face from the vertical. The down-stream face of the dam has a much greater batter than the up-stream face; therefore, in order that the masonry of the down-stream face may not be more severely strained when the reservoir is full than that of the up-stream face when the reservoir is empty a lower limit must be taken for the intensity of the vertical pressure at the down-stream face thus at the up-stream face * * *."

In the present state of knowledge, Rankine did not consider it possible to deduce by mathematics the ratio which the limits of pressure at the up-stream and down-stream faces ought to bear to each other, and, therefore, he fixed the limits which he adopted in designing a profile entirely by what experience had shown to be safe, in connection with masonry dams. The limits of pressure which he adopted are:

	Limits of vertical pressure, in pounds per square foot.
Down-stream face	15 625
Up-stream face	20 000

The same reasoning which led Rankine to recommend a lower limit of vertical pressure for the down-stream than for the up-stream face induced him to make the vertical pressures at the down-stream face diminish as the batter increases. Basing this diminution on practical examples, he designed his profile type so as to have, at a depth of 150 ft., the maximum pressure that occurs in the Furens Dam at the same depth, namely, 6½ kg. per sq. cm., or about 6.65 tons (of 2 000 lb.) per sq. ft. Below this depth, the maximum vertical pressures diminish gradually in Rankine's profile-type.

The conditions given by Rankine do not determine the form of

the profile, but when there is added the practical requirement that, with a view to economy, the profile should have the minimum area consistent with safety, the choice of profile becomes limited. The methods of De Sazilly and Delocre involve lengthy and complicated calculations. Rankine devised simpler formulas for determining the form of a profile. Owing to his having assumed a higher limit of pressure for the up-stream than for the down-stream face, the batter of the down-stream face becomes much steeper than that of the French types. The weight of the water resting on the steep up-stream face of such a profile can add but little to the stability of the dam. Rankine neglected this force in his formulas, as the slight error thus introduced is in the direction of safety. This omission simplifies the formulas. The profile recommended by Rankine is described by him as follows:

"In choosing a form in order to fulfil the conditions, without any practical important excess in the expenditure of material beyond what is necessary, I have been guided by the consideration that a form whose dimensions, sectional area, and center of gravity, under different circumstances, are found by short and simple calculations is to be preferred to one of a more complex kind, when their merits in other respects are equal, and I have chosen logarithmic curves for both the inner and the outer face, the common subtangent being 80 ft. for both." (Fig. 3.)

The formulas given by Rankine for this profile are exceedingly simple, but they give only one profile, the dimensions of which might as well be calculated once for all. If a change is made in the weight of masonry, the limiting pressures, etc., upon which this profile is based, the formulas given are incapable of solution by any direct method, and can only be solved approximately by a process of trial and error involving the higher mathematics. If such a method would give the most economical profile for a dam, there might be no objections to using it; but such is not the case. The logarithmic profile proposed by Rankine is only a rough approximation to the profile of minimum area fulfilling the given conditions, and, if it be continued for a greater depth than 150 ft., the down-stream face becomes so flat that it cannot be used for a practical design.

Rankine appears to have been the only English writer who proposed formulas for calculating an economic profile for a masonry dam. Since the appearance of his report on the "Design and Con-

struction of Masonry Dams," some additional memoirs on this subject have been published in the *Annales des Ponts et Chaussées.*

Bouvier proposed to modify Formulas A, B and C so as to calculate the distribution of the whole resultant of the water pressure and the weight of masonry on an assumed joint at right angles to the line of action of the resultant.

Pelletreau advanced a method of determining a profile-type. By the higher mathematics, he found a simple series expressing the thickness of the dam at any depth, as long as the up-stream face remains vertical. He did not succeed, however, in finding a general formula for that part of a dam where both faces are battered.

A graphic method of finding a correct profile for a masonry dam is given by de Beauve in his "Manuel de l'Ingénieur des Ponts et Chaussées" (Paris, 1878). It gives accurate results, but is laborious.

Krantz proposes some profile-types (Fig. 3) in his book entitled "A Study of Reservoir-Walls" (Paris, 1870), but he gives no formulas for determining their dimensions.

Crugnola, the Italian engineer, likewise has given profiles for masonry dams (Fig. 3), without formulas, in his book on dams (Turin, 1882).

Molesworth, in his pocketbook for engineers, has given empirical formulas for determining the profile of a dam.

The methods of determining the profile of a dam and the proposed types mentioned above are all that the writer was able to find in 1884, when the calculations for the proposed Quaker Bridge Dam were being made. They are all very laborious and more or less complicated, when used for calculating profiles based upon different data as regards weight of masonry, limiting pressures, etc.

In calculating the dimensions of the first profiles for the Quaker Bridge Dam for different data, the writer used a simple process of trial calculation instead of the complicated methods described above. The profiles were based upon the following conditions:

1.—The lines of pressure, reservoir full or empty, must be kept within the center-third of the profile.

2.—The maximum pressures on the masonry or on the foundation must not exceed certain safe limits, a greater

limit of pressure being assumed for the up-stream than for the down-stream face.

3.—The dam must offer sufficient resistance to sliding or shearing.

The distribution of pressure and the resistance to sliding were calculated by the formulas given by De Sazilly.

The width of the profile was determined by trial calculations at regular intervals, usually of 10 or 20 ft. A vertical axis of moments was taken at a convenient distance up stream from the dam, and the positions of the lines of pressure, reservoir full and reservoir empty, were determined at each assumed horizontal joint by taking moments about the axis. The top width of the dam being given, both faces were kept vertical until a joint was reached, at a depth found by trial, at which the line of pressure, reservoir full, just reached the limit of the center-third of the profile. Below this joint the down-stream face was battered so as to keep the line of pressure, reservoir full, just on the limit of the center-third of the dam, while the up-stream face was kept vertical until a joint was reached where the line of pressure for reservoir empty was at the limit of the center-third of the profile. Below this joint both faces of the dam were battered so as to keep the lines of pressure, reservoir full and reservoir empty, just on the limits of the center-third of the profile.

The upper part of the profile was based solely upon the condition that the lines of pressure, reservoir full or empty, should be within the center-third of the profile, as the pressures on the masonry are inconsiderable. After a number of courses had been determined by this principle, a joint was found at which the maximum pressure at the down-stream face reached the given limit. For the next courses, the down-stream face was given more batter so as to keep the maximum pressures at the down-stream face on the given limit, but the batter of the up-stream face was continued so as to keep the line of pressure, reservoir empty, just on the limit of the center-third of the profile, until a joint was reached at which the maximum pressure at the up-stream face was found to be equal to the assumed limit. Below this joint both faces were battered so as to keep the maximum pressures at the faces on the given limits.

From the process described above it will be seen that the joints of the dam are not based upon the same condition. We have, commencing at the top:

1.—A part of the profile where both lines of pressure, reservoir full and reservoir empty, lie within the center-third of the profile;

2.—A part where the line of pressure, reservoir full, lies just on the limit of the center-third of the profile, while the line of pressure, reservoir empty, is within the center-third;

3.—A part where the lines of pressure, for reservoir full and empty, both lie on the limits of the center-third of the profile;

4.—A part where the maximum pressures at the down-stream face just reach the given limit, while the limit of pressure is not yet reached at the up-stream face; and,

5.—A part where the maximum pressures at both faces are kept just on the given limits of pressure.

After the first profiles had been determined for the Quaker Bridge Dam by trial calculations, as described above, the writer devised a simple analytical method of determining the width of the profile of a masonry dam at regular intervals, which was used in the final calculations. It was developed in the following manner:

Assuming the highest water level at the top of the dam, and taking, for convenience in the calculations, 1 cu. ft. of masonry as the unit of weight or pressure:

Let a = the top width of the dam;
x = the unknown length of a joint of masonry;
l = the known length of the joint above x;
h = the vertical distance between l and x;
u = the distance of the line of pressure, reservoir full, from the down-stream edge of x;
n = the distance of the line of pressure, reservoir empty, from the up-stream edge of x;
m = the distance of the line of pressure, reservoir empty, from the up-stream edge of l;
v = the distance on the joint, x, between the lines of pressure, reservoir full and reservoir empty;
d = the depth of water at the joint, x;
r = the specific gravity of the masonry;

$H = \frac{d^2}{2\ r}$ = the horizontal thrust of the water above x;

$M = \frac{d^3}{6\ r}$ = the moment of the water relative to x;

W = the weight of the masonry resting on x;

w = the weight of the masonry resting on l;

R = the resultant of H and W;

p = the limiting pressure per square foot at the down-stream edge of x;

q = the limiting pressure per square foot at the up-stream edge of x.

The vertical component of the water pressure on the up-stream face of the dam is neglected, as recommended by Rankine, as the trifling error thus made is in the direction of safety.

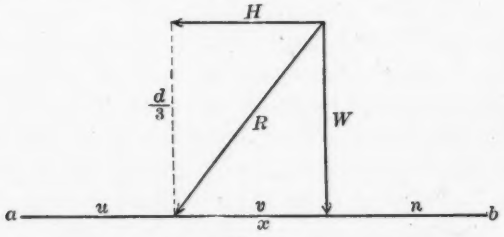


FIG. 4.

The lines of pressure, reservoir full and empty, divide each assumed horizontal joint of the dam into three parts (Fig. 4). For the joint, x:

$$x = u + v + n \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

As $$M = W\,v, \text{ then } v = \frac{M}{W}.$$

Assuming each course of masonry to be bounded by straight lines, then

$$W = w + \frac{(l + x)\ h}{2}.$$

Substituting in Equation 1 for v the value, $\frac{M}{W}$, and for W the value, $w + \frac{(l + x)\ h}{2}$, we obtain

$$x = u + \frac{M}{w + \frac{(l + x)\ h}{2}} + n \quad \ldots\ldots\ldots\ldots\ldots (2)$$

By substituting in Equation 2 for u and n the proper values resulting from the given conditions, the minimum thickness of a dam can be calculated at intervals as close as desired. In the upper parts of the dam, where the only requirement is to keep the lines of pressure within the center-third of the profile, we must write:

$$u = \frac{x}{3}, \text{ and } n = \frac{x}{3}.$$

When the limiting pressures, p and q, are reached, the values of u and n are obtained from Formula A, namely:

$$u = \frac{2\,x}{3} - \frac{p\,x^2}{6\,W}; \text{ and } n = \frac{2\,x}{3} - \frac{q\,x^2}{6\,W}.$$

As far as the thrust of the water is concerned, the top width of a dam might theoretically be 0; but, as the dam must also resist the shocks caused by waves and floating bodies, the top must have a certain width, and this is to be determined solely by practical considerations. Generally, the top is made sufficiently wide to serve as a roadway. Whatever the width assumed, it gives the dam an excess of strength at the top to resist the thrust of the water. In order to reach the minimum width of profile to resist this thrust, both faces of the dam must be kept vertical until a joint is reached at which the line of pressure, reservoir full, is just at the limit of the center-third of the profile. The depth at which this joint will be found can be ascertained from Equation 2 by making the following substitutions:

$$x = l = a;\ u = \frac{a}{3};\ n = \frac{a}{2};\ h = d;\ w = 0;\ M = \frac{d^3}{6\,r}.$$

After reducing,

$$d = a\sqrt{r} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

For the next courses, the down-stream face must be battered so as to keep the line of pressure, reservoir full, on the limit of the center-third of the profile; but the up-stream face must be kept vertical until a joint is reached where the line of pressure, reservoir empty, lies on the limit of the center-third of the profile. Between this joint and the one formed by Equation 3, there will be several joints having $u = \frac{x}{3}$, and $n > \frac{x}{3}$. The value of n may be found by taking moments around the up-stream face of the dam and placing

the moment of the whole weight equal to the sum of the moments of its parts. In this manner it will be found that

$$n = \frac{(x^2 + l\,x + l^2)\,\frac{h}{6} + w\,m}{w + \frac{(x+l)\,h}{2}}.$$

Substituting in Equation 2, $u = \frac{x}{3}$, and the above value of n, we obtain, after reducing:

$$x^2 + \left(\frac{4\,w}{h} + l\right) x = \frac{6}{h}(w\,m + M) + l^2 \ldots\ldots\ldots (4)$$

This equation may be used for a number of joints until one is reached where the line of pressure, reservoir empty, is on the limit of the center-third of the profile. Below this joint both faces of the dam must be battered so as to keep the lines of pressure, reservoir full and reservoir empty, on the limit of the center-third of the profile.

For these joints we must place

$$u = \frac{x}{3}, \text{ and } n = \frac{x}{3}, \text{ in Equation 2.}$$

After reduction, we obtain:

$$x^2 + \frac{(2\,w + l)\,x}{h} = \frac{6\,M}{h} \ldots\ldots\ldots\ldots\ldots (5)$$

Equation 5 can be used until a joint is reached where the maximum pressures on the masonry reach either the limit, p or q. As it has been assumed that $p < q$, according to Rankine's recommendation, the limit of pressure will be reached first at the down-stream face. For these joints, Formula A gives

$$u = \frac{2\,x}{3} - \frac{p\,x^2}{6\left[w + \frac{(x+l)\,h}{2}\right]},$$

and

$$n = \frac{u}{3}.$$

Substituting these values in Equation 2, and reducing, gives

$$x^2 = \frac{6\,M}{p} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

This equation may be used for a number of joints, until one is reached where the pressure at the up-stream edge equals the limit, q. Below this joint the pressures, both at the down-stream and the up-

stream faces, must be kept at the given limits, and therefore, from Formula A:

$$u = \frac{2\,x}{3} - \frac{p\,x^2}{6\left[w + \frac{(x+l)\,h}{2}\right]},$$

$$n = \frac{2\,x}{3} - \frac{q\,x^2}{6\left[w + \frac{(x+l)\,h}{2}\right]}.$$

Substituting these values in Equation 2, and reducing, gives

$$x^2\,(p + q - h) - 2\,x\left(2 + \frac{l\,h}{2}\right) = 6\,M. \quad \ldots\ldots\ldots (7)$$

From Equations 3 to 7, inclusive, may be calculated the width of the profile at intervals. If these intervals are sufficiently small (about 10 ft.), the change from one equation to the next comes so gradually that there is no difficulty in knowing which to use. Equations 6 and 7, which apply to that part of the profile where both faces are battered, give the lengths of the joints, but do not fix their position with reference to a vertical axis, for which purpose the following two auxiliary equations are required. They give the amount of batter of the up-stream face for the course in question. This batter, which is denoted in the formulas by y, is found by taking moments about the up-stream edge of the joint, x.

For the joints found by Equation 6:

$$y = \frac{2\,w\,(x - 3\,m) - h\,l^2}{6\,w + h\,(2\,l + x)} \quad \ldots\ldots\ldots\ldots\ldots (8)$$

For the joints found by Equation 7:

$$y = \frac{w\,(4\,x - 6\,m) + l\,h\,(x - l) + x^2\,(h - q)}{6\,w + h\,(2\,l + x)} \quad \ldots\ldots (9)$$

Equations 3 to 9, inclusive, were used for determining the profile of the Quaker Bridge Dam above the river-bed. For the part below the river-bed, the equations were modified so as to include the weight of the saturated gravel resting on the dam. The modified equations were derived by the late Ira A. Shaler, M. Am. Soc. C. E., who calculated the final profile adopted for the Quaker Bridge Dam. They will not be given here, as they are very lengthy.

The profile of the Quaker Bridge Dam was based upon the data and conditions stated in Table 1.

TABLE 1.—QUAKER BRIDGE DAM.

	Elevations.	
	Croton datum *	Referred to bed-rock.
Top of dam	210	262
Highest water level	206	258
River-bed	35	87
Bed-rock	—52	0
Base of dam	—58	—6
Top width of dam		20 ft.
Weight of masonry, per cubic foot		156¼ lb.†
Weight of water, per cubic foot		62½ lb.
Weight of saturated gravel and sand in river-bed, per cubic foot		145.88 lb.‡

One cubic foot of masonry was taken as the unit of weight.

* Mean tide at the mouth of the Croton River.
† Corresponding to a specific gravity of 2½.
‡ This weight was found by assuming the sand and gravel to weigh 125 lb. per cu. ft., and assuming one-third of its bulk to be filled with water.

Limits of Pressure.—From the top of the dam to Elevation 110 the pressures in the masonry, at the up-stream and down-stream faces, were limited to 20 625 and 16 400 lb. per sq. ft., respectively. (Corresponding to 10 and 8 kg. per sq. cm.)

From Elevation 110 to the base of the dam, the pressures were allowed to increase gradually, reaching a maximum of 30 000 lb. per sq. ft. at both faces of the base.

The full water pressure was assumed to act as far as the base of the dam, but no upward pressure under the base was taken into account. The vertical component of the water pressure on the up-stream face of the dam was neglected, as recommended by Rankine.

In order to form a practical design, the theoretical profile found in the manner described above was modified slightly, as follows:

1.—The top width was increased by corbeling out to give the width required for a roadway.

2.—The outlines were simplified by substituting a few simple batters for the many changes occurring in the faces of the theoretical form.

3.—In the final calculations the dam was given a superelevation of 4 ft. above high water, and the thickness of the profile, for a depth of 40 ft. from the top, was increased slightly to make it more symmetrical, and to provide additional strength to resist the shocks from floating bodies.

4.—The sharp triangle at the down-stream toe of the dam was

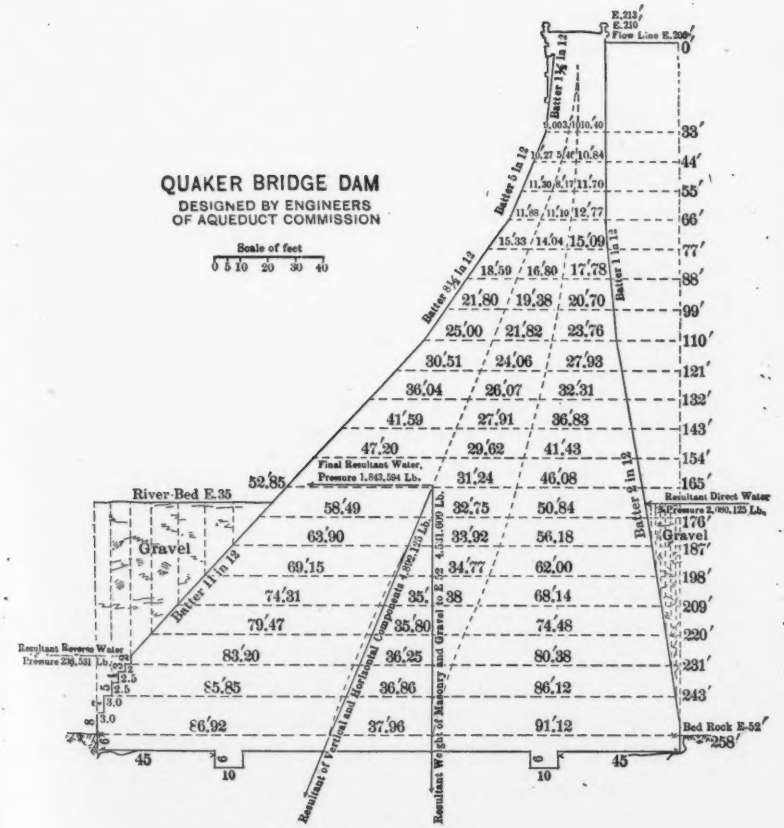

QUAKER BRIDGE DAM
DESIGNED BY ENGINEERS
OF AQUEDUCT COMMISSION
Scale of feet
0 5 10 20 30 40
E. 213′
E. 210
Flow Line E. 205′
Batter 1½ in 12
Batter 5 in 12
Batter 6¼ in 12
Batter 1 in 12
Batter 2 in 12
Batter 11 in 12
0
33′
44′
55′
66′
77′
88′
99′
110′
121′
132′
143′
154′
165′
176′
187′
198′
209′
220′
231′
243′
258′
Bed Rock E. 52′
River Bed E. 35
Gravel
Gravel
52.85
Final Resultant Water Pressure 1,843,594 Lb.
Resultant Direct Water Pressure 2,080,125 Lb.
Resultant Reserve Water Pressure 236,531 Lb.
Resultant of Vertical and Horizontal Components 4,592,195 Lb.
Resultant Weight of Masonry and Gravel 4,511,600 Lb.
45
10
10
45

FIG. 5.

cut off, as it was not considered to have sufficient strength to distribute the pressure of the masonry, and the face was carried up in steps for a certain height. This reduced the width of the base from 230 to 216 ft., and increased the pressures on the masonry at the down-stream face to 33 266 lb. per sq. ft. Fig. 5 shows the profile finally adopted.

Having designed the profile by this method, the next question considered was whether the dam should be straight or curved in plan. Good examples of each plan of construction existed. For a curved plan, calculations were made to ascertain whether the area of the profile could be reduced on account of the additional strength that might be due to arch action. That such action might take place was shown by the fact that two curved dams—the Zola Dam, in France, and the Bear Valley Dam, in California—resisted the water pressure successfully, although the lines of pressure for reservoir full fell outside of the profiles of the dams. These dams, therefore, owed their stability solely to arch action, as they were unable, by gravity, to resist the water pressure. In both these cases the dams were constructed across narrow valleys.

The Zola Dam was built about 1843. Its height is 119.76 ft. above the foundation, and its width is only 41.82 ft. at the base. Its length is 205 ft. on top, and it is curved in plan, the radius at the crest of the dam being 158 ft. When the reservoir is full, the line of pressure falls about 11.50 ft. outside of the base of the foundation.

The Bear Valley Dam was constructed in 1884 in the Bernardino Mountains, in California. The profile adopted was so thin that the line of pressure, reservoir full, fell almost wholly outside of the dam. This dam, which has been replaced by a stronger one built below the first site, had a maximum height of 64 ft. above the foundation, and was 3.17 ft. wide on top and 20 ft. wide at the base. It was curved up stream to a radius of 335 ft.

While these two examples proved that in the case of a narrow valley a dam might resist the water pressure by acting as a horizontal arch, calculations showed that in a curved dam built across a wide valley, like that of the Croton River, arch action would produce far greater strains in the masonry than those which would occur in a dam designed to resist the water pressure by weight alone.

The pressures in a curved dam were ascertained by supposing the dam to be divided into horizontal courses, each of them forming a ring composed of a number of voussoirs. The pressure in such a ring, which is exposed in a horizontal direction only to the water pressure acting normally to its surface, is found by the well-known formula:

$$T = p\,r,$$

in which

T = the uniform thrust in a circular ring;
p = the pressure per unit of length of the ring;
r = the radius of the ring's outer surface.

This formula applies to a circular ring of masonry, but, evidently, it may be imagined that part of the ring is removed and replaced by the practically rigid sides of the valley, in which case the formula would still be applicable.

The authorities consulted agreed that very little reliance could be placed on calculations treating a dam as a horizontal arch, and that a curved plan for a dam should only be adopted for a narrow valley.

Delocre states that a dam will cease to act as an arch when the width of the dam equals one-third of the radius of the curve, or is larger.

Pelletreau advises that the arched plan should not be adopted when the dam is more than 131 ft. in height and length.

Krantz gives the limit of span for an arched dam as 131 ft., with a radius of not more than 65.6 ft.

Rankine says that "in the present state of science, the calculations of stability, treating the dam as a horizontal arch, are so uncertain as to be of doubtful utility." He recommends that a dam be always built sufficiently strong to resist the thrust of the water by its own weight, and that in the case of a narrow valley the plan be curved so as to add some additional stability to the structure.

In their reports to the Aqueduct Commissioners on the design and construction of high masonry dams, dated July 28th, 1887, both Mr. B. S. Church, Chief Engineer, and Mr. A. Fteley, who had resigned as Deputy Chief Engineer and was Consulting Engineer

at the time, advised that the plan of the Quaker Bridge Dam be made straight, for the following reasons:

1.—A dam of the length of the proposed Quaker Bridge Dam (1 350 ft. at the crest) would be exposed to excessive strains if it acted as an arch.

2.—If designed to resist the water pressure by its weight alone, as recommended by Rankine, it would not yield sufficiently to cause arch action.

3.—If no arch action should occur, the curving of the plan would involve a waste of money, as it would increase the volume of masonry.

The conclusions arrived at by Messrs. Church and Fteley were fully concurred in by the engineers of the Department of Public Works.

The next important feature considered was the superelevation to be given the dam above the highest assumed flood level (Elevation 206). This was determined from the data of existing dams and from practical considerations. The top of the dam was placed 4 ft. above the flood level, and the top of the stone parapet 3 ft. higher, which was considered sufficient to prevent the highest waves that might occur from breaking over the top of the dam.

One of the most important questions to be decided was the length of the overflow weir. At the Old Croton Dam, which is about 4½ miles above the site selected for the Quaker Bridge Dam, the maximum flood recorded produced a flow of 8 ft. 2 in. deep over the overflow weir, the length of which is 251.4 ft. The water-shed above the dam contains 338.82 sq. miles. It was decided to make the overflow weir of the Quaker Bridge Dam sufficiently long to be able to discharge in 24 hours a volume of water represented by a uniform thickness of 6 in. over the whole water-shed, which contains about 361 sq. miles. The length of overflow corresponding to these conditions was calculated to be about 1 300 ft. In view of the fact, however, that the dam was to be provided with blow-off gates, and that one, if not both, of the Croton Aqueducts would be drawing water from the reservoir, it was decided to give the overflow weir a length of 1 000 ft.

In reference to the kind of masonry: the plans contemplated the use of uncoursed, broken-range rubble masonry, built of quarry stone of irregular sizes, laid with full beds and joints. Cut stone was only to be used for ornamentation, where required.

On account of the importance of the proposed Quaker Bridge Dam, and the opposition to its construction, the Aqueduct Commissioners, on March 7th, 1888, appointed a Board of Expert Engineers to take into consideration the plans prepared by the engineers of the Commissioners and the modifications which had been or might be suggested by others, either in plan or in cross-section, and to advise the Commissioners fully on these subjects. Joseph P. Davis, M. Am. Soc. C. E., J. J. R. Croes, Past-President, Am. Soc. C. E,, and Mr. Hermann Schussler, were appointed on this Board. Mr. Schussler could not serve, and Mr. William F. Shunk was appointed in his place. After a thorough investigation of the questions submitted, the Board of Expert Engineers, on October 1st, 1888, made its report to the Aqueduct Commissioners. The forces to which the dam might be exposed were classified in this report, as follows:

1.—The quiescent and ever-acting forces, such as the weight of the masonry and the pressure produced by the impounded water;

2.—Forces produced by the expansion of ice in place, or by floating masses;

3.—Forces produced by waves of translation, the possible cause of such waves being the giving way of a dam above, or an extensive land slide;

4.—Earthquake shocks.

The experts assumed the following data:

Top of parapet of dam	Elevation 214	
Highest water level	" 202	
River-bed	" 35	
Bed-rock	" —52	
Weight of water per cubic foot	62.5	lb.
Top width of dam	20	ft.
Weight of masonry per cubic foot	146.25	"
Ice pressure per linear foot	43 000	"

With reference to the pressure of ice, the experts stated:

"In our search for information upon the expansive force of ice in place, caused by increase of temperature, we found little of value recorded; but we obtained valuable, though somewhat conflicting, information by correspondence and personal interviews, which information, supplemented by experimental data, concerning its strength, elasticity and rate of expansion under a rising thermometer, has led us to the opinion that the dam should be proportioned to resist a thrust at the highest ice line of about 43 000 lb. per lin. ft.

"More positive information was available regarding the force exerted by ice flow. Under certain unfavorable conditions, when ice jams form in a quick running current, it appears to be almost irresistible by direct opposition. But, as in the case of the Quaker Bridge Dam, the water current, when there is one, will tend to direct the flow away from it, and direct impact can be produced only by sheets of ice driven by the wind, we have concluded that, if the dam be proportioned to resist the pressure of 43 000 lb. per lin. ft., above mentioned, it will be of ample strength to withstand the attack of floating masses."

To secure the dam from injury by waves of translation, its upper portion, where the effect of such waves would be greatest, was designed to have a coefficient of at least 2 against overturning, when the level of the water might be at the top of the parapet.

Earthquake shocks may vary from a slight tremor to an immeasurable force. The experts stated that, if the dam be proportioned to resist the forces already mentioned, it would have ample stability to withstand all but shocks of the severest nature.

The profile designed by the experts was made to comply with the following conditions:

1.—The factor of safety against overturning shall be at all points at least 2;

2.—The ratio of the weight of masonry above any horizontal plane or point to the maximum force tending to cause sliding or shearing along the plane shall not be less than 3 to 2;

3.—The maximum quiescent stress on the down-stream end of the joints at the river-bed (Elevation 35) shall not exceed 20 000 lb. per sq. ft.;

4.—Below the river-bed, when the strength of the masonry to resist crushing is aided by the lateral pressure of

the earth, the maximum quiescent stress shall not exceed 28 000 lb. per sq. ft.

5.—The pressures on the joints may be somewhat greater at the up-stream face than at the down-stream face, as they will be permanently reduced as soon as the reservoir begins to fill.

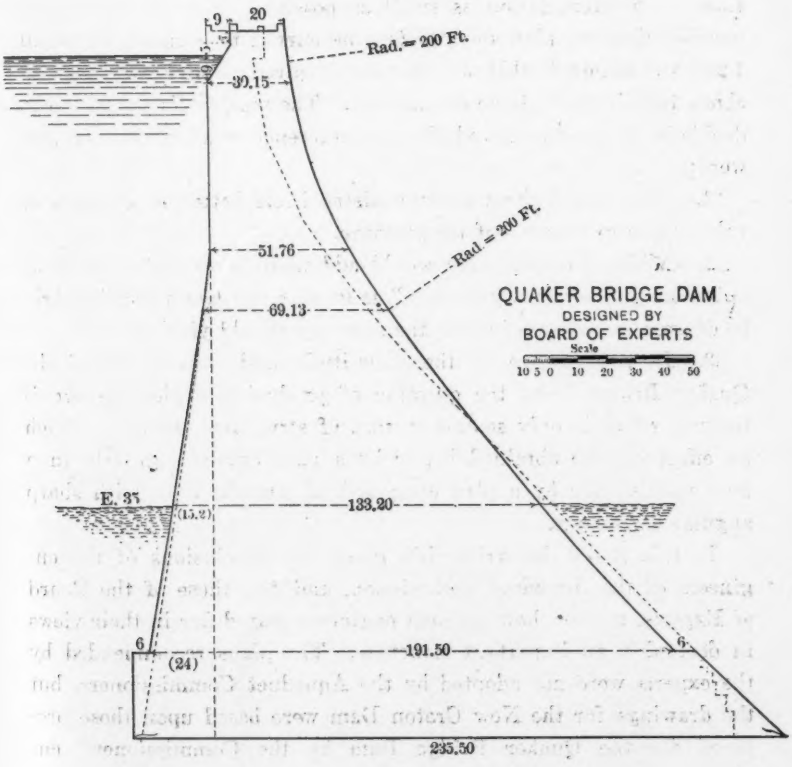


FIG. 6.

The profile designed by the Board of Experts to comply with the conditions given above and, also, the profile recommended by the engineers of the Aqueduct Commission, are shown in Fig. 6.

The former profile is thicker in its upper part than the latter. The experts thought this increase in thickness necessary to give the

dam sufficient strength to resist the shock of ice and excessive freshets.

In making the final location of the dam, the engineers of the Aqueduct Commission had staked out the axis of the dam on two straight lines, respectively 326 and 1 077 ft. long, the angle between the two lines being about 45 degrees. This was done, in accordance with the information obtained by test borings, to make the excavation for the foundation as small as possible. The experts recommended that the plan for the dam be curved to a radius of about 1 200 ft., although this would have involved a slight increase of about 10% in the volume of masonry. The reasons that made them decide in favor of a curved plan in preference to a straight location were:

1.—The curved form accommodates itself better to changes of volume due to changes of temperature.

2.—While a curved plan would add nothing to the stability of a dam having a "gravity section," as long as the dam stood, it might be of great advantage in case the masonry should yield.

3.—In a structure of the magnitude and importance of the Quaker Bridge Dam, the question of producing a pleasing architectural effect is only second to that of structural stability. Such an effect can be obtained better by a plan curved regularly in a long radius than by a plan composed of straight lines with sharp angular deflections.

In this paper the writer has given the conclusions of the engineers of the Aqueduct Commission, and also those of the Board of Experts, to show how eminent engineers may differ in their views in designing an important structure. The plans recommended by the experts were not adopted by the Aqueduct Commissioners, but the drawings for the New Croton Dam were based upon those prepared for the Quaker Bridge Dam by the Commissioners' engineers.

Discussion of the Plans Adopted.—Considering the protracted studies made in designing the profile for the Quaker Bridge Dam, one would expect to find the profile finally adopted about as perfect as was possible with the knowledge available at the time. Such, however, does not seem to the writer to be the case, for reasons which he will give. The profile was based on the conditions pro-

posed by Rankine, but, on account of the unprecedented height of the dam, greater limits of safe pressure had to be assumed in the lower parts of the structure than had been recommended by Rankine. One of the points in which Rankine had improved on the methods adopted by the French engineers was in assuming a lower limit of pressure at the down-stream than at the up-stream face of the dam, the limits adopted by him for a dam 180 ft. high being, respectively, 15 625 and 20 000 lb. per sq. ft. In designing the profile for the Quaker Bridge Dam, the maximum pressures assumed in the calculations were, according to Mr. Fteley, Consulting Engineer at the time and later Chief Engineer of the Aqueduct Commission,* for a depth of water of 110 ft. or less, 16 400 lb. per sq. ft. at the down-stream face and 20 625 lb. per sq. ft. at the up-stream face. From a depth of water of 110 ft. to the base of the dam the maximum pressures in the masonry were allowed to increase gradually until they reached a maximum of 30 000 lb. per sq. ft. at both faces at the base of the dam. The pressure at the ends of the different assumed horizontal joints of the theoretical profile, as given by Mr. Fteley,† are shown in Table 2.

TABLE 2.—THEORETICAL PROFILE FOR QUAKER BRIDGE DAM.

Elevation of joint. Croton datum. Feet.	Depth of water at joint, in feet.	PRESSURES AT ENDS OF JOINTS, IN POUNDS PER SQUARE FOOT.	
		Down stream.	Up stream.
171.3	34.7	13 031	6 516
156.	50.	14 156	11 328
136.	70.	15 234	15 234
116.	90.	15 984	15 984
96.	110.	16 391	17 453
76.	130.	16 384	18 462
56.	150.	17 078	19 930
35.	171.	18 219	21 822
15.	191.	20 084	23 641
−5.	211.	22 680	25 466
−25.	231.	25 691	27 313
−52.	258.	30 000	30 000

The profile to which Table 2 applies seems to be somewhat inconsistent, for the following reasons:

1.—Greater pressures are allowed at the up-stream than at the

* Report to the Chief Engineer, July 25th, 1887.

† Table II of Mr. Fteley's Report.

down-stream face, until the base of the dam is reached, where the pressures are made the same at both faces. Why should not a difference in pressure be made at the base, as in the upper parts of the dam?

2.—The pressures at the down-stream and up-stream faces, respectively, were limited to 16 400 and 20 625 lb. per sq. ft., to a depth of 110 ft. of water, which was assumed arbitrarily. Below this depth, the pressures were allowed to increase gradually. What object was accomplished in limiting the pressures as described above to a depth of 110 ft. when, below that depth, they were allowed to increase? Would it not have been more logical to have designed the upper part of the profile solely with a view of confining the lines of pressures, reservoir full or empty, to the center-third of the profile, and to have allowed the pressures to increase gradually until some assumed limits of maximum pressures for the down-stream and the up-stream faces of the dam were reached, below which point the profile should have been designed so as to keep the pressures at the ends of the joints exactly at the prescribed limits?

The theoretical profile discussed above was slightly modified to meet some practical requirements, as already explained. The modifications changed the distribution of pressures in the masonry somewhat; these are given in Table 3* for the final profile.

TABLE 3.—PROFILE ADOPTED FOR QUAKER BRIDGE DAM.

Elevation of joint. Croton datum. Feet.	Depth of water at joint, in feet.	PRESSURES AT ENDS OF JOINTS, IN POUNDS PER SQUARE FOOT.	
		Down stream.	Up stream.
173	33	8 588	6 578
151	55	12 425	11 973
129	77	14 716	14 960
107	99	15 891	16 797
85	121	16 544	18 291
63	143	16 966	19 688
41	165	17 997	21 578
19	187	19 672	23 609
—3	209	22 406	25 563
—25	231	26 156	27 609
—52	258	33 266	30 828

* Table III of Mr. Fteley's report.

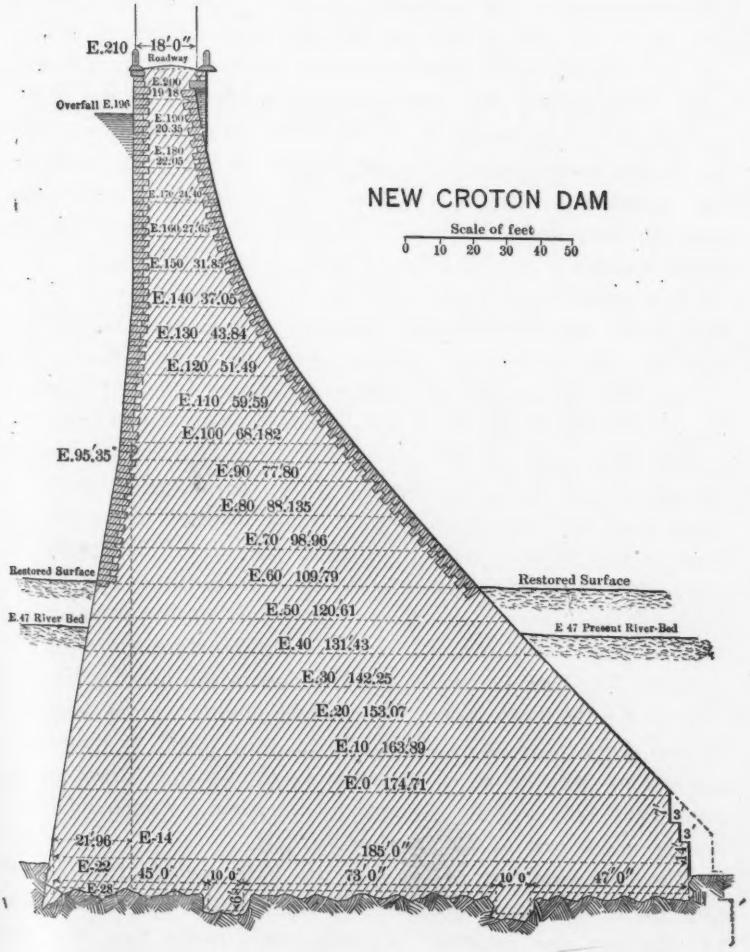

E.210
18′0″
Roadway
Overfall E.196
E.200 19.18
E.190 20.35
E.180 22.05
E.170 24.40
E.160 27.35
E.150 31.85
E.140 37.05
E.130 43.84
E.120 51.49
E.110 59.59
E.100 68.182
E.95.35
E.90 77.80
E.80 88.135
E.70 98.96
E.60 109.79
E.50 120.61
E.40 131.43
E.30 142.25
E.20 153.07
E.10 163.89
E.0 174.71
NEW CROTON DAM
Scale of feet
0 10 20 30 40 50
Restored Surface
E.47 River Bed
Restored Surface
E.47 Present River-Bed
3′
3′
11′
21.96
E-14
E-22
E-28
45′0
10′0
185′0″
73′0″
10′0
47′0″

FIG. 7.

According to Table 3, the distribution of pressure is worse in the modified than in the theoretical profile, the pressure at the base, in the former, being greater at the down-stream than at the up-stream face. This is principally due to the fact that part of the toe of the dam at the down-stream face was cut off and replaced by steps. The writer does not think it was necessary to make this change. The pressure to be distributed at the face is not vertical, but, according to Rankine, parallel with the face; the batter immediately above the steps is the same as at the toe of the theoretical profile, and there appears to be no good reason why the face should be broken into steps at the down-stream toe, while remaining battered immediately above the steps.

The contract plans for the New Croton Dam were not made until about five years after the studies for the Quaker Bridge Dam had been concluded. No further calculations were made. Mr. Fteley, who had become Chief Engineer of the Aqueduct Commission, based the profile upon the design he had prepared for the Quaker Bridge Dam, the only difference being that the down-stream face of the profile for the latter was rounded off in its upper part by the introduction of more changes of batter, the area of the profile being also slightly increased. The profile of the New Croton Dam given in the contract drawings (Fig. 7) has polygonal outlines, which, in the upper part of the down-stream face, approach closely to a curve. In constructing the dam, the Division Engineer in charge fitted curves to the angular line intended for the down-stream face. Three circular curves separated by two short tangents of 22 and 26 in. were used. It would certainly have been better if, in preparing the contract drawing, the profile had been slightly changed by adopting a compound curve for the upper part of the down-stream face.

The up-stream face of the dam was built vertical from Elevation 140 to the top of the dam (Elevation 210). Below Elevation 140 the face was battered. A profile could easily have been designed with the up-stream face vertical from the top of the dam to the refilling (Elevation 70), and would have been more easily followed in construction. The water pressure against a dam is represented graphically by a triangle, and the theoretical profile of minimum area to resist the water pressure is also a triangle until

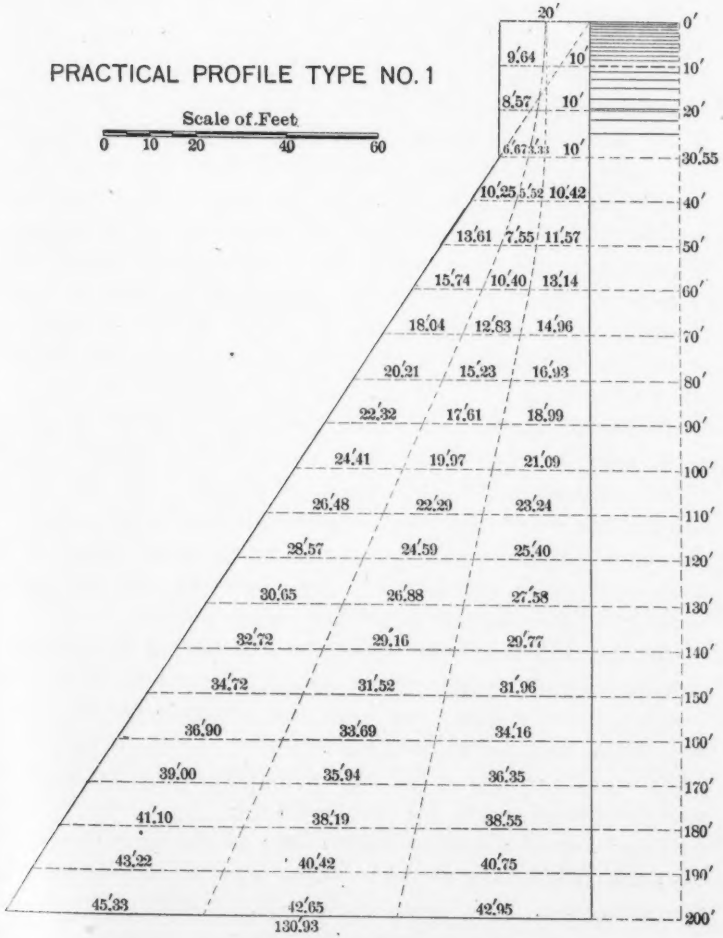

PRACTICAL PROFILE TYPE NO. 1
Scale of Feet
0 10 20 40 60
20′
9′64
10′
8′57
10′
6′67
10′
10′25
5′52
10′42
13′61
7′55
11′57
15′74
10′40
13′14
18′04
12′83
14′96
20′21
15′23
16′93
22′32
17′61
18′99
24′41
19′97
21′09
26′48
22′29
23′24
28′57
24′59
25′40
30′65
26′88
27′58
32′72
29′16
29′77
34′72
31′52
31′96
36′90
33′69
34′16
39′00
35′94
36′35
41′10
38′19
38′55
43′22
40′42
40′75
45′33
42′65
42′95
130′93
0′
10′
20′
30′55
40′
50′
60′
70′
80′
90′
100′
110′
120′
130′
140′
150′
160′
170′
180′
190′
200′

FIG. 8.

the pressures in the masonry reach the given limits (Fig. 8). The nearer the practical profile approaches a triangle, the greater the economy will be.

To resist the action of waves, and shocks from floating bodies, a dam must have a certain thickness at the top, which may have to be increased if it is to have a roadway. The effect of this increased width is to augment the dam's strength to resist overturning or sliding; it adds only a trifling amount to the pressures in the masonry. If the thickness added at the top of a dam be taken into account in the calculations, the most economical profile type is that shown by Fig. 9, but as the area of this profile, down to a depth of 150 ft., is only about 5% more than that of the simple triangular profile type shown in Fig. 8, the writer thinks the latter is to be preferred on account of its simplicity. Such a profile, if continued to a depth of 200 ft., would produce a maximum pressure of 30 320 lb. per sq. ft., if the masonry has a specific gravity of $2\frac{1}{3}$.

As regards the location of the New Croton Dam, it is greatly to be regretted that the site was changed from Quaker Bridge, $1\frac{1}{4}$ miles up stream, to that known as Cornell's. At the former site the dam would have been founded entirely on gneiss; the overflow would have taken place through a lateral valley; about $1\frac{1}{2}$ sq. miles would have been added to the water-shed, and the storage capacity of the reservoir would have been increased.

At the Cornell site the waste water could not be discharged through a lateral valley without considerable expense, and therefore Mr. Fteley designed the waste weir to adjoin the main dam. In order to keep the waste channel in rock, which was only to be found near the surface at the north side of the valley, and to obtain also the desired length for the waste weir (*i. e.*, 1 000 ft.), the weir was located almost at right angles to the main dam, along the north hillside, and joined by curves with the hillside and with the main dam. This location, while it provided an excellent waste weir and channel, involved considerable expense. In constructing the weir and channel, about 120 000 cu. yd. of earth, and about 240 000 cu. yd. of rock were excavated, and about 90 650 cu. yd. of masonry were laid.

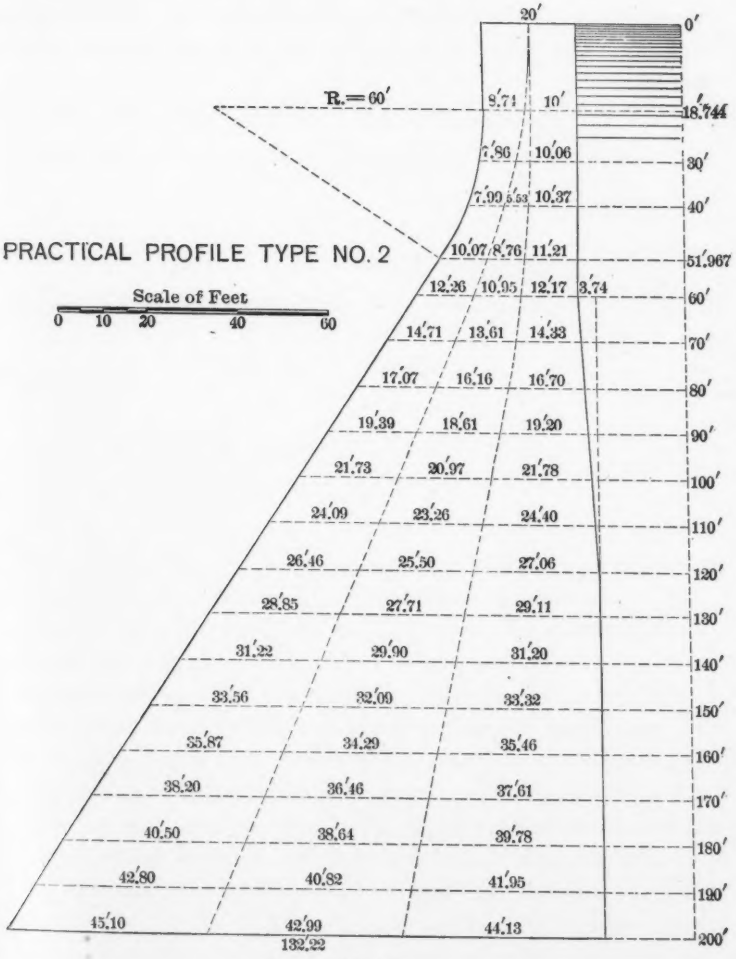

PRACTICAL PROFILE TYPE NO. 2
Scale of Feet
0 10 20 40 60
R.=60′
20′
0′
9′.71
10′
18′.744
7′.86
10′.06
30′
7′.99
5′.53
10′.37
40′
10′.07
8′.76
11′.21
51′.967
12′.26
10′.95
12′.17
3′.74
60′
14′.71
13′.61
14′.33
70′
17′.07
16′.16
16′.70
80′
19′.39
18′.61
19′.20
90′
21′.73
20′.97
21′.78
100′
24′.09
23′.26
24′.40
110′
26′.46
25′.50
27′.06
120′
28′.85
27′.71
29′.11
130′
31′.22
29′.90
31′.20
140′
33′.56
32′.09
33′.32
150′
35′.87
34′.29
35′.46
160′
38′.20
36′.46
37′.61
170′
40′.50
38′.64
39′.78
180′
42′.80
40′.82
41′.95
190′
45′.10
42′.99
44′.13
200′
132′.22

FIG. 9.

The writer has given herein some criticisms of the profile of the New Croton Dam, considered as an engineering design. In doing so, however, he does not mean to imply that the dam is not sufficiently strong to resist the pressures to which it is exposed. The reservoir has been filled to Elevation 182 (14 ft. below the top of the depressed spillway), and the dam has been found to be satisfactory in every respect.

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PAPERS AND DISCUSSIONS.

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UNIFORMITY OF REQUIREMENT AND CLEARNESS OF SPECIFICATION IN AGREEMENTS FOR THE GRADUATION OF RAILROADS.

By W. F. Dennis, M. Am. Soc. C. E.

To be Presented March 6th, 1907.

The construction and betterment of the subgrade of railroads is a large business, affecting the expenditure of hundreds of millions of capital and calling for the services of thousands of engineers and contractors.

A somewhat extended experience in this class of construction, partly as engineer and partly as contractor, has impressed upon the writer matters which, in his opinion, are worthy of consideration in the preparation of agreements for such work. The magnitude of the business, the large number of individuals interested, and the benefit to their business relations which would result from any advance toward uniformity of requirement, increased clearness of specification, and reduction of friction in carrying agreements into effect, are the reasons for presenting this paper, in which some of the matters covered in contracts for graduation will be considered.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

Classification.

Nearly all railroads find it useful to retain classifications in their forms of agreement. Such classifications give a solid rock material at one end, and an earthy material at the other, with, generally, an intermediate material called loose rock, and frequently an additional hardpan classification, formerly more common than now.

Classifications grew out of a recognition that different materials varied in cost of removal. Each classification was an attempt at segregating material into groups of approximately similar cost. The theory was that, "not being able to see under the ground," if the contractor, in making a proposal for certain work, had to guess at his unit costs for each material, and, in addition, had to approximate the relative quantity of each, he would have to provide against a double hazard. Having a classification, he could guess with some accuracy, from his experience, the cost of the different materials under the given conditions, and eliminate the hazard of their proportion.

Where the experience of the subordinates, who do the actual classifying, of the management, and of the contractors, is fairly well established for a particular section, the theory works out well, with very little friction, and, in the writer's opinion, with cheaper final results to the railroad and more satisfactory results to the contractor—cheaper and more satisfactory because of the elimination of part of the risk.

Twenty-five years ago an unclassified price was exceptional; today much the larger volume of excavation is paid for unclassified. If any tendency can be discerned, it is strongly in the direction of letting all excavation unclassified; or of limiting it to one classification for rock, and another for all other materials.

On the part of the railroads there is the argument that classification is prolific of lawsuits, and there is an unfounded belief that an unclassified price prevents them. Besides this, and outside of all other considerations, the growth of business brought about by consolidations and extensions leaves scant time for investigation, and it is increasingly difficult in practice for the Chief Engineer really to go into or review any classification.

There is also a process of extension of operations and centralization in management in the contractor's business. On different roads

he observes classifications which are not exact, even by definition, largely modified by custom, and finds that custom varying with individual engineers in charge, and, from time to time, even upon the same railroad. However exact the contractor's estimate may be, on what he considers a proper classification, he is practically at sea as to what is to be paid. Should he bid upon an anticipated favorable classification, it might be changed during the progress of the work; if he assumes the unfavorable, possibly he may lose the work. In addition, he thinks that he has clearly detected instances where classification was influenced downward by financial considerations, pressure from the management, preliminary estimates being exceeded, and so on.

As a result of these uncertainties, the writer believes that most of the responsible contractors of to-day, in weighing the two hazards —their own both as to proportion and cost of materials, or the other as to what kind of classification they will get from the engineer— generally prefer to take their own risk upon an unclassified price. In making an unclassified price, either from necessity or choice, the contractor not uncommonly finds difficulty in getting bidding information which is sufficiently clear as to quantities and disposition of material. Some engineers present a profile, but refuse to give quantities in detail, being afraid that claims may be made if there be any change. Contractors, to keep their business going, are compelled to bid in the form in which the engineers, their customers, require. Under such circumstances they make the best approximation possible; but when full information is not available there is less competition, and the work goes, not to the best-informed or best-equipped competitor, but to the most optimistic. It is economically wrong to let the work too high or too low, and the engineer is inexcusable who does not secure and present clearly every piece of information that will eliminate the risk of the work as much as possible.

In spite of the apparent satisfaction of both sides with the unclassified price, the writer believes that it is not right in principle, and that paying by a proper classification is, in the long run, the most equitable and reasonable method.

It is worth while to find out if there may not be some position that will shape the theory into a more workable practice. The in-

quiry can cover only two points: is the average classification sufficiently explicit; and, if not, can it be made more so?

As before stated, the basis and aim of classification are to associate in one group classes of material for which the cost of handling is supposed to be approximately the same. The class, location and magnitude of the work, and the kind of equipment which is best adapted to it, have a very important bearing upon the cost, even of the same material. The association of one material with another on the basis of similar cost, therefore, might be proper in one case and not in another. Confusion from this influence, and attempts at designating material by names and qualities at the same time, cause uncertainty in existing classifications. For work suitable only to scrapers, it is inconsistent to embrace, in the same classification, earth, sand, gumbo and cemented gravel as apparently equivalent. If it is assumed that the work is to be done by steam shovel, many of the items of loose-rock cost for hand work will approximate the cost of an equal quantity of earth.

The company agrees to pay definite prices for definite services in a definite time. The contractor thereupon proceeds to perform the service, providing such appliances as his judgment, particular plant, or financial ability, will justify. If he knows exactly how he is to be paid, from a well-understood classification, or similarly with an agreed unclassified price, he can then make his calculations as to heavy-plant expense and lower working cost, or the reverse, and longer or shorter time. It would be in the highest degree inconsistent if large plant investment should cut down the classification; yet one specification, the writer remembers, classified a material as loose rock if moved by hand, and as earth if moved by steam shovels. If a classification is desirable in itself, this principle seems to be clearly wrong. The classification of a given material should be rigid, for removal by any appliance, and irrespective of quantities or location. If special appliances can reduce cost, competition will make the reduction appear in the price for the classification. From every point of view, the classification should be made, not by names and descriptions of material, but by some definite physical characteristic susceptible of uniform test.

Is it practicable to make a test upon the materials generally found in excavation for public work? As a first criterion, a simple,

measurable test, easily applicable, and defining what should be properly in the "earth" classification, is whether or not the material can be plowed in its natural state by a definite plow pulled by a definite number and weight of stock. Whether this material is moved by scraper, grader, cart, car, wheel-barrow, or steam shovel, what is meant is clearly described, namely a material which a designated plow will produce in shoveling condition. This description excludes from the earth classification some material included in some earth specifications, and includes some material which, in others, is classed as loose rock or as hardpan. As will be seen later, earthy material, not included in the "earth" classification, goes to an intermediate classification, for convenience and other considerations, termed "loose rock."

The reason for placing the earthy material, sometimes included in earth and hardpan classifications, in the loose-rock classification, is the obvious one of similarity of cost. If the material is too wet to be plowed, as in case of swamp muck, quicksands and some gumbos; or is too hard to be plowed, like hardpan, cemented gravel, etc., holding to the proper theory of grouping by rough similarity in cost, no designation by name can properly make it "earth," in a cost sense, for all appliances, although it might be for some. Additional costly work may be required to get the material loaded or transported. In some cases the cost of unplowable earthy material may approximate and exceed that of solid rock; but, speaking generally, the cost is somewhat similar to the cost of loose rock, and such material is most fairly included in that classification.

Preliminary to the consideration of a physical test for solid and loose rock, the following definitions have been abstracted from current specifications:

Solid Rock.

New York, New Haven and Hartford.—"All rock or stone containing one cubic yard or more." (All other material is earth.)

Erie.—"Rock in masses exceeding one cubic yard, which cannot be removed without blasting."

Pennsylvania.—"Rock in masses exceeding one cubic yard, which cannot be removed without blasting."

Baltimore and Ohio.—"Rock in solid beds or masses, which may be best removed by blasting."

Chesapeake and Ohio.—"Rock in ledges and detached masses exceeding one-half cubic yard, which may best be removed by blasting."

Norfolk and Western.—"Rock in masses which may best be removed by blasting."

Southern.—"Rock in masses of more than one cubic yard, which may be best removed by blasting."

"Big Four."—"Stone in solid masses or ledges."

Chicago, Burlington and Quincy.—"Stratified rock weighing more than 140 lbs. per cubic foot, which can only be removed by blasting."

Chicago and Alton.—"All stratified rock and rock occurring in masses which can only be removed by blasting * * * must ring under hammer."

Great Northern.—"Rock in place, in removing which, it is necessary to resort to drilling and blasting."

Atchison, Topeka and Santa Fé.—"Rock in solid beds or masses in its original or stratified position * * * other material which can be removed without continuous drilling and blasting, but which is as difficult * * * as solid lime or sandstone."

Illinois Central.—"Rock in solid beds or masses in its original position * * * which may best be removed by blasting." (Everything else classed as "common excavation.")

Northern Pacific.—"All rock in masses that cannot be removed without drilling and blasting."

Missouri Pacific.—"Rock in solid beds or masses, in its original position, which can only be removed by continuous blasting."

What is "rock" and "stone"? Notice the following definitions:

Standard Dictionary.—*Rock.*—"The consolidated material forming the crust of the earth * * * not excluding beds of clay or sand * * * a rock may consist of one mineral species, as limestone, or of several intermingled, as granite * * * massive rock, a rock that does not exhibit foliation or schistose structure."

Stone.—"A small piece of rock. Rock as a material, a piece of rock shaped for a specific purpose. Synonyms, boulders, cobble, mineral, gem, pebble."

Century Dictionary.—*Rock.*—"The mass of mineral matter of which the earth, so far as accessible to observation, is made up; a mass, fragment or piece of the crust, if too large to be designated as a stone. The unconsolidated stony materials which form a considerable part of the superficial crust, such as sand, gravel and clay, are not commonly designated as rock or rocks; the geologist * * * includes under the term rock * * * all of the consolidated materials form-

ing the crust, as well as the fragmental or detrital beds which have been derived from it."

Stone.—"A piece of rock. The name rock is given to the aggregation of mineral matter of which the earth's crust is made up. A small piece or fragment of this rock is generally called a stone."

Webster's Dictionary.—*Rock.*—"Any natural deposit forming part of the earth's crust, whether consolidated or not."

Stone.—"Concreted, earthy or mineral matter * * * also any particular mass of such matter. In popular language, very large masses of stone are called rocks; small masses are called stones; and finer kinds, gravel or sand."

Gillette's "Rock Excavation."—"Rocks are aggregates of one or more minerals, or the disintegrated products of minerals."

These definitions do not help to clear up any uncertainties there may be in railroad classifications.

Loose Rock.

Erie.—"Slate, shale or other rock which can properly be removed by steam shovel, pick or bar, without blasting, although blasting may be resorted to on favorable occasions to facilitate the work * * * detached masses, 3 cu. ft. to 1 cu. yd."

Pennsylvania.—"Stone and detached rock lying in separate and continuous masses containing not over one cubic yard; also all slate or other rock that can be quarried without blasting, although blasting may be occasionally resorted to."

Baltimore and Ohio.—"Slate, coal, shale, soft friable sandstone and soapstone, detached masses 3 cu. ft. to 1 cu. yd."

Chesapeake and Ohio.—"Shale, slate, ochre, which can be removed with pick and bar, and is soft and loose enough to be removed without blasting, although blasting may be occasionally resorted to. Detached masses 3 cu. ft. to 1 cu. yd."

Norfolk and Western.—"Shale, soapstone, and other rock which can be removed by pick and bar, and is soft and loose enough to be removed without blasting, although blasting may be occasionally resorted to. Detached masses 1 cu. ft. to 1 cu. yd."

Southern.—"Soapstone, shale and other rock which can be removed by pick and bar and is soft and loose enough to be removed without blasting, although blasting may be occasionally resorted to. Detached stone 1 cu. ft. to 1 cu. yd."

"Big Four."—"Shale, coal, slate, soft sandstone, soapstone, conglomerate stratified limestone in layers less than 6 in.—detached masses 3 cu. ft. to 1 cu. yd."

Chicago, Burlington and Quincy.—"Stratified rock which can be removed by pick and bar weighing more than 140 lbs. per cu. ft. Detached masses 3 cu. ft. to 1 cu. yd."

Chicago and Alton.—"Stratified rock which can be removed by pick and bar * * * and masses between 3 cu. ft. and 1 cu. yd."

Great Northern.—"Slate and other rock, and loose enough to be removed without blasting, although blasting may be occasionally resorted to—detached masses 3 cu. ft. to 1 cu. yd."

Atchison, Topeka and Santa Fé.—"Hard shale or soapstone * * * in original or stratified position, boulders in gravel, cemented gravel, hardpan * * * and other material requiring * * * use of pick and bar or which cannot be plowed with 10-in. plow and 6-horse team."

Illinois Central.—(No loose rock. Everything but solid rock classed as common excavation.)

Northern Pacific.—"Slate, soft sandstones, or other rock than can be * * * removed without blasting * * * detached rock between 1 cu. ft. and 1 cu. yd."

Missouri Pacific.—"All rock * * * which requires for its removal steam shovel or pick and bar, without blasting, although blasting may be resorted to at the option of the contractor. Detached masses 1 to 18 cu. ft."

A composite view of the several descriptions of rock and loose rock would reduce to about this: Rocky material which can be removed without blasting is loose rock; and that which cannot is solid rock. That word, "can," is the whole of the question, the uncertainty of the answer to which causes most of the disputes about classification. The word "can," is complicated by the fact that it is nearly always cheaper to blast so-called loose rock than pick or bar it apart, and, further, undeniably solid rock can be disintegrated by slow degrees without blasting. The word "can," then, for reasonable interpretation, depends upon some rate of removal. A solid mass of rock might be seamy to the extent of permitting wedging or barring out 1 or 2 cu. yd. per day, but that possibility does not make it loose rock. On the other hand, a certain material might be dug slowly by a steam shovel without blasting. If it could be loaded faster, as a result of blasting, it would be taken out customarily by blasting, but, under the specification, that fact would not necessarily make the material solid rock. On the other hand, the same material, under nearly all specifications, might be solid rock by reason of the impracticability of removing it with pick or bar with reasonable rapidity.

Taking a general view, the difference between materials in a

construction sense is obtained by the writer from consideration of the operations necessary in loading such material on their transporting appliances. Earth is a material which can be reduced to loading condition by plowing, or equivalent inexpensive picking or blasting. Loose rock is a material which generally can be put into handling shape by picking, barring and light sledging, or, in lieu thereof, by moderate blasting, but it is not quite as easy to load as earth. Solid rock is a more refractory material, requiring drilling, strong explosives, and general sledging, and, with this additional expense, is not capable of reduction to a loading condition as favorable as the other materials. In seeking for some limit between solid and loose rock, it is impracticable to fix any rate of drilling or quantity of explosive. The condition after blasting cannot be taken as a guide, because that will depend upon the foregoing, as well as upon the cohesion of the material. The requirement of ringing under the hammer is inapplicable; the expression, "continuous blasting," is inexact, and can be worked as a swindle by either side.

Can a physical uniform test be applied? It is known that certain soft or fractured rocks can be picked or barred apart with reasonable rapidity, and customary specifications state the fact, but do not state the rate. By definition of that rate the classifications of rock can be clearly defined. The writer thinks that, keeping close to current practice in classification, the rate of disintegration for loose rock should be within the performance of two men thus employed. A material requiring more than two men working with pick and bar to keep one shoveler busy is certainly a material that "may better be removed by blasting" and which "can only be removed by blasting," in a reasonable sense.

It may be objected that this criterion would throw some material, occasionally understood as loose rock, into the solid-rock classification. The writer does not think this would be the case, if the ordinary "loose-rock" specifications mean what they say. But, if so, the point is, that the cost of material under any classification is not a fixed cost, but varies with many factors. For instance, a material unquestionably solid rock, under certain circumstances, might be loaded for 40 cents per cu. yd.; under other circumstances, identically the same rock, physically and chemically, might cost $1, $3, or more, per cu. yd. Fixing a standard by which the contractor

can know clearly how the material will be paid for is not going to make the price for the classification. That price will be made on the average cost of the materials included, as modified and governed by the specific conditions of place and removal, embracing the whole subject of quantity, appliance, situation, credit and labor.

A consideration of importance is the size of the rocky mass that must be exceeded in order to constitute a solid-rock classification. In hand-work an isolated mass of 3 cu. ft. can be handled without much difficulty; but any larger mass will require disintegration before loading. The expense of this disintegration per cubic yard will be higher than that for disintegrating masses of the same material which, under any size limit, would still be solid rock. In steam-shovel work very considerable masses can be loaded without disintegration, and, consequently, without much real extra expense. An objection to a small size limit would be an apparent necessity for more particularity of measurement. As to that, the separate quantities in mixed material, in practice, are approximated percentages, and are as easy to calculate, with one size limit as another. Bearing in mind the theory of trying to fix classification by similarity of cost, the writer thinks that 1 cu. yd.—the limit most frequently specified—is too high; 3 cu. ft., although right in one view, is probably too low; and that the compromise limit of ½ cu. yd. would be about right. This limit was formerly common, and is still retained in some specifications.

In an endeavor to set forth the foregoing more clearly, the writer proposes the following as an outline classification:

> Excavation, excepting foundation pits for structures, elsewhere classified separately as foundation excavation, shall be either classified or unclassified, as may be determined at the time of the contract. If classified, the following classification shall apply:
>
> *Earth.*—Material which in its customary natural condition can be plowed—or is equivalent to a material which can be plowed—with a plow cutting a furrow 10 in. wide and 10 in. deep, drawn by a team of 4 horses, or mules, each having an average weight of 1 100 lb., and moving at a reasonable plowing speed, shall be classified as earth.

Loose Rock.—The following shall be classified as loose rock: Earthy or mixed materials, not susceptible of plowing under the foregoing test; soft, fractured, disintegrated or other rocky material, soft or loose enough in its natural condition to be barred or picked apart by two men thus employed serving one man shoveling or loading by hand; solid rock in separate masses exceeding 1 cu. ft. each, and not exceeding ½ cu. yd. The continuous or occasional use of explosives, at the contractor's option, shall not affect the classification, but it shall be governed solely by the test above set forth.

Solid Rock.—The following shall be classified as solid rock: Rocky material in masses exceeding ½ cu. yd., which cannot be broken apart, or displaced from its natural position, except by the use of explosives; and other rocky material which cannot be picked or barred apart by two men thus employed serving one man shoveling or loading by hand.

Where any excavation contains material of more than one classification, the relative percentage of each shall be determined by measurement and observation during the progress of the work.

The principal point aimed at is clearness of test and classification. Experiment will determine whether or not the material can be plowed, and actual picking or barring of the material will determine whether or not two men can keep one shoveler going. Classification becomes, not a matter of opinion, but of demonstration. As illustrating the application of these tests to bidding: if, under the test, the principal earth material upon a piece of work could not be plowed, and, therefore, would be classed as loose rock; and if the intention was to move it by steam shovel; and if competing contractors considered that with their appliances there was little difference in cost between the given material and earth, they would bid about the same price for loose rock and earth. Under other conditions they might justifiably find that the price of the given material had to be two or three times that of plowable earth,

and bid accordingly; the classification, in other words, does not make the prices. Rigidity of classification simply makes clear how a given material is to be paid for. With this information, the price for the material can be made intelligently by the contractor in view of his experience with similar material and his knowledge of local conditions.

For heavy steam-shovel work, the writer's opinion is that there is no especial benefit in a distinction by classification between loose rock and earth, and, for that class of work, a classification for solid rock and another for all other material would be sufficient; but nearly all steam-shovel work involves more or less miscellaneous accessory work for team and hand appliances, and the loose-rock classification is needful for them; furthermore, classification on all work would become better established by its uniform practice.

Foundation Excavation.

Almost universally, specifications provide payment for excavating foundation pits for structures. Formerly, these were generally paid for on a percentage basis; but there was frequent opportunity for dispute, mainly on account of differences of opinion as to the kind and extent of appliances to be furnished and the proper compensation for them.

Some specifications provide for payment for the material in coffer-dams as well as for excavation. Here the dispute comes as to the necessary quantity of excavation and the form, material and size of the coffer-dam, all of which are under unspecified control. Other specifications settle this by requiring the engineer to make plans for the coffer-dams. This is impracticable on account of delay, and throws the responsibility on the engineer, who is not generally as well qualified as the contractor to make an economical design. The most frequent custom, and apparently the best, is to leave the material and design of the coffer-dam or support to the contractor, make him responsible and pay by some definite stipulation. Past experience should give the contractor a fair idea of the cost of ordinary foundations, and the conditions of more important emplacements can be studied before bidding; so that, on the average, there should be sufficient information in sight to make a fairly

reasonable estimate. Experience shows that the reliable unit to be used in computation is the cost of the excavated material per cubic yard. Specifications do not generally define the quantity of material which shall be measured. The following seems to the writer to be reasonable practice and definition:

Excavation for foundations of pipes, masonry, or other structures, shall be classified as foundation excavation under the following heads:

Dry-Foundation Excavation.—Material of whatever nature, excepting solid rock, found above water level;

Rock-Foundation Excavation.—Material, elsewhere defined as solid rock, found above water level;

Wet-Foundation Excavation.—All material below water level.

By "water level" is meant the average or mean level during construction at which pumping or bailing becomes necessary in the work of excavating. The quantity of wet excavating shall be computed as a prism having a height equal to the distance between the average level of the bottom of the foundation pit and the water level and a base equal to the area of the foundation course plus 4 ft. all around. The dry and rock excavation quantities shall be computed on a base equal to the bottom area of the wet excavation as above defined, with the necessary slopes to the natural surface.

Wet excavation shall include the cost of excavating, piling, coffer-dams, pumping, bailing, leveling off the bottom, and the expense, of whatever nature, necessary to complete the foundation pit from low-water level to the level finally determined for the bottom, and to maintain the foundation pit open until the structure shall have been placed therein, not, however, including the placing of iron, timber, or piles, in permanent artificial foundations, these items being paid for under a separate schedule elsewhere described.

The prices for all classes of foundation excavation shall include the cost of removing the spoil, and depositing it in adjoining fills, or of wasting the spoil, if such de-

posit in fills be not required by the engineer; and also the cost of removing such portions of coffer-dams as the engineer may require, for appearance or for reducing obstruction to the waterway.

Measurements.

Every now and then textbook misinformation is seen in attempts to measure excavation by the prismoidal formula. For that formula to apply strictly, every point of the surface between the end cross-sections should be capable of generation by a straight line moving on the two end areas. No natural ground corresponds exactly to this theoretical requirement. The middle area is the dominant factor in the calculation, and how may this be obtained correctly? If not cross-sectioned, it must be computed from the end-area dimensions, and this calculation produces an area which is entirely imaginary and certainly out of place in a rigid formula. If a middle area is measured, thereby doubling the number of cross-sections, it will still have to be demonstrated that the solid is a correct prismoid. Using each section in turn as a middle area and halving the totals is theoretically preposterous. The ordinary measurement, by averaging the end areas, cannot, in Nature, represent the mathematical mean area. Neither this nor the prismoidal formula, therefore, gives absolutely rigid measurement. Decision must be made as to which approximation is to be taken. Averaging end areas is simple, quick, and natural in principle, easier to apply, has the sanction of custom, and is on the whole fairly exact. Cross-sections for any formula have to be located by the judgment of the field engineer. Any reasonably experienced man will locate sections sufficiently close together on rough ground to reduce the theoretical error of the end-area computation to a small percentage. The writer has a strong feeling that, in staking out work, the ordinary record of the measurement will vary from the accurate delimitation of the true solid more than the difference that will appear by juggling the record between the two methods of computation.

In the absence of a precise specification for the use of the prismoidal formula, custom would legally govern the method of calculation. Even in the event that the prismoidal formula was specified, the writer does not believe it would hold, because it could not be

demonstrated to be mathematically correct in its application to construction cross-sections. With a specification calling for what could be proved to be an incorrect method of measurement, the customary method, it is believed, would control in any controversy. Using the prismoidal formula in the computation of construction quantities is an attempt at substituting something apparently ultra-scientific for a very simple computation. The use of "corrections" to approximate end-area computation to the prismoidal formula appears to be still more objectionable, not having the alleged rigid accuracy of the prismoidal formula, and, as far as the writer can see, requiring nearly as much extra work, with very free chances for error.

Right or wrong, the kind of quantities produced by averaging end areas is the kind sanctioned by custom, and in some States required by law. Any use of the prismoidal formula in construction computation is unwarranted as a matter of right, and very wrong as to policy. The contractor will surely put it down to "skinning," although the only motive may be a desire to be more scientific than others.

Extra Items Included in Prices for Excavation.

In the cost of excavation many requirements are frequently included which do not properly belong there, such as fencing right of way during construction, maintenance of road crossings, temporary bridges, saving and piling rock, opening "horseback" roads, taking material across streams, rip-rapping slopes, benching embankments, spreading material in layers, packing around masonry, and, worst of all, including the cost of foundations in the price of masonry. All these matters cost money. They may or may not be done. Quantity and cost are indeterminate.

The specifications appear to assume that their cost is considered and added to the excavation prices; but the quantity of excavation is rarely known accurately in advance, and, generally, the extent and amount of the extra requirements are absolutely unknown. Under this theory, therefore, a portion of the excavation price is for something which does not belong to it. The engineer, therefore, is either paying for something which is not done, or not paying properly for it, as the case may be.

The general rule of business should apply here. Where a defi-

nite thing is to be done, it should be paid for directly. Matters problematical in extent should not be called for, except with the promise of definite reimbursement. One matter should not carry the cost of another matter, unless the latter be uniformly a concomitant of the first and is specified so definitely that its quantity and cost can be calculated. A simple, direct way is to pay stipulated prices if these matters are wanted; or, in lieu of that, to pay for them as extra work.

The current objection to settling these matters as extra work is strongly ingrained, but the authority for them being granted, where is the real difficulty? The argument will be made that the general office has to pass upon an extra bill which cannot be checked. In answer to this, it would seem reasonable to claim that the construction engineer who is reliable enough to classify and measure quantities running to tens and hundreds of thousands of dollars would be competent to investigate correctly occasional bills running to a few hundreds, and that his signature should settle the account.

The human nature side is that the contractor, when he does these things, sees that he has to do them without direct compensation. In preliminary cost estimates, no such accuracy is possible as to have these matters valued correctly in advance. If that view be correct, the engineer, by paying these extras direct, would get his excavation price lower.

A liberal policy in all these matters, as against a rigid requirement, will affect the aggregate of the contract to a very small percentage; but it will eliminate much useless friction and dispute, and the engineer will benefit his company in the long run by establishing a reputation for liberality and fairness at a very small temporary expense and a real saving.

Making Embankments.

The survival of an error which once gets into print is well illustrated by the frequent specification: "Embankments must be carried up in layers of 2 ft."; "materials shall be deposited and distributed as the engineer may direct." The writer has known two instances where inexperienced resident engineers attempted to enforce the requirement, but has never yet seen a railroad fill made in 2-ft. layers. The absurdity of such a requirement is well illus-

trated by considering steam-shovel work. It is believed that this requirement, in actual expense and delay, would mean that the dumping expense alone on heavy earthwork might cause an extra cost of more than the contract price. If the question was between the ordinary method and this requirement, would the engineer with such a specification feel warranted in paying the extra cost and carrying out the requirement, from any supposed advantage to be thereby obtained? A similar question arises as to the segregation of materials. It is absolutely impracticable, under working conditions, to do anything else than take the material and dump it as it comes. Where top or slope rock dressing on fills is called for, it can hardly be gotten, as a general proposition, except by dumping selected material and reloading. Would any engineer be willing to arrange all his work with the top dressing and pay the cost as an extra? These requirements are not generally enforced, and competition compels the contractor to disregard such problematical expenditures, even though the right to them be specified clearly. Every now and then the requirement is enforced, and it is a clear case of the contractor doing extra work for nothing.

These requirements in railroad construction are for things absolutely without any practical value; they are unmeaning when not enforced, and a dead expense when required, and should be eliminated. On the occasions when such requirements are really necessary, the fair way is to pay for them, and not try to get them done for nothing under a blanket clause.

Overhaul.

The remarks as to specific compensation apply partially to clearing, grubbing and overhaul, but the latter are more definitely ascertainable by the contractor before bidding. On new lines, generally, there is often insufficient information and time for minute examination. Relocation of the line and grade frequently destroys any calculation. With no price for these items, where is the equity between the company and the contractor where extensive changes are made during construction? As an extreme case, suppose a steam-shovel section 5 miles long, with no overhaul clause; suppose the location of the borrow is not shown at the letting; suppose that available borrow exists, with a high-priced or unobtainable right

of way near a fill at one end, and that a long-haul borrow, with no cost for land, is available at the other. Has the company a right, in saving right-of-way expense, to force the contractor into hauling, say 4 miles, under a stipulation of no payment for changes or for overhaul?

The overhaul is like the unclassified price—legally enforceable only upon a specific line shown to the contractor at the letting of the work. Speaking in a general sense, any hardship that comes upon the contractor, from changes, will legally release him from the contract, unless they are adjusted to his satisfaction. With no overhaul specified, there is no base agreed upon for change.

The writer admits that there is complication in the overhaul question, arising from what is a proper overhaul distance to specify. A 1 000-ft. overhaul on steam-shovel work may be immaterial, but it is a very serious matter for team haul. The difference could be taken up by specifying that locomotive overhaul price shall apply beyond a certain distance, and on team overhaul beyond a shorter distance. On work which, by reason of location, small magnitude, or for other cause, naturally requires hand or team appliances for excavation, the overhaul price would be made for these appliances, and would generally be high enough to require wasting and borrowing before the proper limits of steam-shovel haul were reached. Where steam shovels, wholly or in part, are anticipated, the overhaul price will come down to such an extent that there will be no controversy as to appliances, because it will be uneconomical to make any team overhaul for the price of locomotive overhaul. In sections where scrapers are the ruling appliances, specifications give properly low limits for the commencement of overhaul—300, 500 and 600 ft.; 1 000 ft. is common elsewhere, and, occasionally, 1 500 and 1 600 ft. For team appliances, 1 000 ft. is too high; 1 500 ft. entirely unreasonable. The nonsensical stipulation, of an overhaul after an average haul on the section or contract, has about disappeared, so that nothing need be said in criticism. For steam-shovel overhaul, there is no standard of custom. Some roads pay under the general overhaul; some include it in the yardage price. Practically, it is a question of track cost as one item, variable per cubic yard, with the yardage per unit of track; of maintenance-of-way; and of the point where extra trains become necessary. The

latter distance is dependent upon factors not connected with length of haul, facility of dumping, and facility of loading and speed.

To have more than one overhaul price or distance might be conducive to conflict between the contractor and the engineer as to the proper equipment for the work. Inasmuch as the contractor, in making the proposition, must have in mind the appliances by which he expects to move the material, he should have the ability to adjust differences and work out an overhaul price that will represent the average. The handicap to this is the customary lack of full bidding information. Whichever view is taken, it is not of great importance, provided the overhaul principle is accepted and a clear description is given of how it is to be calculated.

There is considerable difference in the practice of estimating overhaul, and confusion as to just what it means. The customary meaning of overhaul is, that every yard of material moved, over and beyond the free-haul distance, is subject to the contract allowance for overhaul. This carries the implication, as is also the common understanding, that the free overhaul distance shall be measured on the route actually taken by the hauling appliance used; that the route be of grades customary for such appliance; and that the appliance be appropriate to the particular case. In the event of, say, a 100-ft. cut into a 100-ft. fill, it can be seen that the question of proper grades and appliances might become very complex. To avoid controversies, the method of measuring overhaul should be stated clearly so that the contractor, in bidding, could cover the ordinary hauls, as well as the special hauls called for by exceptional conditions. The simplest method would be to locate the stations of free haul, and then deal with the cut and fill on either side by locating the station of the center of mass of each. These points could be identified and understood during construction, and the overhaul computation could be checked at any subsequent period. Unless the method of calculating the haul be defined, the common usage will prevail, the effect of which is that, at a later date, no man can check another, or even himself.

Clearing and Grubbing.

There is nothing to be said specially on these items; as a business policy, they should be paid for specifically, on the ground that they have no uniform relation to grading.

Sub-Contracting Work.

It is as usual to see agreements specify that no work is to be sublet as it is to see, in the execution, sub-contractors more or less peacefully performing their assigned tasks. What is the purpose of the prohibition? It is generally a dead letter in the enforcement. The writer cannot think that experienced engineers consider it a system of double profit. If it is, is not the contractor, having obtained his work in competition, entitled to share his profit with the sub-contractor, if he is so generously inclined? The sub-contractor exists because his services in detail, as foreman, manager, or contractor, coupled with his financial interest in results, and his special plant, are at times more efficient than can be obtained in other ways.

If sub-contractors are eliminated entirely, how would the contractor class be recruited? Most successful contractors develop as sub-contractors before they qualify for a larger field. If the prohibition, except on consent of the engineer, exists, and the sub-contractor is there, in any controversy that may result, the engineer's knowledge of that fact, the giving of instructions, or any form of recognition, will be as binding upon the company as a formal written permission. The inclusion in the contract of a prohibition to be waived in ordinary practice does not safeguard the engineer in the event of litigation. The writer believes it to be against the interest of the company to try to exclude subletting. The only objection that can be brought seriously against the practice is in case of failure, or litigation on account of the sub-contractor; but, in this case, under any customary contract, the company still holds the contractor for the financial end.

The most reasonable view is not to prohibit a perfectly business-like arrangement, but frankly admit it, and, in admitting it, control the form. A stipulation that would seem to cover the whole case would be to require the sub-contractor's agreement to read something like this:

"The company and the contractor shall have all rights and power as to the sub-contractor, that the company has as to the contractor, in its contract with him; and the work assigned to the sub-contractor shall be done subject to all the conditions stated in the specifications of the company, or embodied in the contract between the company and the contractor."

In practice, the sub-contractor's agreement would be a duplicate, except as to principals and price, of the agreement between the company and the contractor, with the foregoing provision added.

As the more successful sub-contractors become contractors and then competitors, the only people really interested in opposing them are the contractors themselves. They might be said to be opposed to subletting work as a principle, but in actual practice they find that, for portions of their work, the arrangement is the least costly and most efficient method of producing a certain result.

If the engineer proposes clearly and firmly to prohibit any form of sub-contracting for an individual piece of work, consideration of policy on the part of the contractor would generally prevent serious opposition, because, no matter what his rights or desires might be, the engineer would have the power to withhold future invitations. On extensive constructions of 20 or 100 miles of railroad, or more, necessitating simultaneous construction from a number of camps, there is no price obtainable by the engineer as advantageous to the company as that which he will get from contractors competing with the expectation of sub-contracting considerable portions of the work. The engineer, by letting a great many small contracts, may think that he will get a lower price; but those engineers who try it do not generally endorse this method.

Contractors have a notion that a contract is a sort of property; that they have the right to make performance by the most suitable method; and that they have as much natural right to make payment by quantity as by time, for services of individuals or groups of individuals. Some of these rights appear to be pretty strong. Sub-contracting occasionally gives the engineer some personal trouble—it rarely gives his company any financial trouble—where there is a sub-contractor there is generally an economic reason. All this means that enforced prohibition of all sub-contracting by everybody will raise the price of work, in the long run; and the engineer cannot justifiably take the position that, in order to avoid some detail and the possibility of annoyance, he may take the risk of increasing the cost of the work. The point will be made clearer by considering the architects: Their clients have chances for liens, suits, etc., to a far greater extent than railroad companies have from sub-contractors, yet it is well known that the average building has as

many sub-contractors as there are trades represented; and they are there because that is the cheapest arrangement for the owner.

Right of Way.

One of the scandals of railroad construction is the absolute disregard of plain business methods in the acquisition of right of way, and the consequent unfair saddling of useless expense on the contractor. It is a notorious fact that, in general, the construction contract is let with little or none of the right of way secured. The contractor sometimes gets on the ground before the right of way agent. That agent's interest is to get right of way for the least money. He may consider that a $20 difference may justify withdrawal for a month, or throwing the case into court in order to sustain his prestige. He is held responsible for the results, has a hard job, and must play all the politics he knows. From his standpoint, his action may be right. Suppose the contractor is held up at a critical point of the work; the other's right is not right for him. His contract says he must wait the other's convenience, whether he likes it or not, and shall lose the time and expense of waiting. This is not a fancy picture, but a daily occurrence.

Many engineers allow themselves to be hustled into starting work with immature plans and without right of way. They would have an easier time, save money for everybody, and do the right thing, if they consistently refused to let contracts until these matters were thoroughly in hand.

Insurance.

Agreements generally contain amplified stipulations that construction must be maintained by the contractor until the final acceptance by the engineer. This seems fair enough on its face, but the customary wording does not make equitable distinctions. It is easy enough to see that if the contractor, in such an act as transporting material to the work, suffers loss or damage of that material before it is put into the structure, the company has equitably nothing to do with the damage.

Further, it is not unreasonable that a structure, such as a building, completed in advance of other work, all subject to acceptance at one time, should be insured by the contractor. The question be-

comes somewhat involved in the instance of, say, trestle-work which has been finally completed, in the event of destruction from a cause, not the fault of the contractor, before acceptance of the work as a whole. For railroad embankments washed away by water; for the destruction of masonry already laid according to specifications; for subsidence of embankments and collapse of slopes, and re-dressing necessary from that cause; and, for similar matters, it is clear to the writer that there is no equitable reason why these risks should be forced upon the contractor. If the contractor places the material where he is directed, no stretch of imagination could make it fair for him to be responsible for destruction by the elements when he has no control over the selection of the location or plan.

As illustrative of the way in which equities are destroyed by such clauses, the writer recalls a case where a retaining wall which was too light fell down when the embankment was placed against it. The wall was rebuilt, payment for it denied, and the contractor sued. He established the fact that the wall fell because of improper design, and that the workmanship was according to contract. He lost on the ground that his contract was not only to build, but to maintain until acceptance, and his remedy would have been to have notified the engineer that the design was insufficient and to have made formal protest to building it.

The writer recalls a personal experience in building a 30-ft. arch. This arch was built on a cemented gravel foundation which was perfectly satisfactory to the engineer and would have been all right ninety-nine times out of a hundred. The side-walls and four cross-walls were carried well down, and the bottom was paved with heavy stone on edge, well laid. The whole work was built under continuous inspection, and the destruction hereafter referred to revealed no fault of workmanship or material.

This arch was accepted on a Friday. In the meantime the fill had been completed for part of its width over the arch, damming the small valley except for the arch opening of about 25 by 30 ft. On the following Tuesday, a cloudburst occurred, and the arch ran full and discharged as a pipe. The paving was dug out by the current, then the gravel was eroded, the side-walls fell in, and the disrupted structure was spread over three acres of ground.

The first question asked by the management was whether or not

the contractor was responsible under the "insurance clauses." This was disposed of by the technicality that the arch had actually been accepted a few days before. Suppose the accepting engineer had been delayed on Friday and calculated to get there on Tuesday, instead; then a strictly technical construction of the agreement would have involved the contractor in replacing 3 000 yd. of masonry at his own expense. What had the contractor done, or not done, that could have made any real change in the equity of his position?

According to the teaching of the case first cited, the contractor's legal duty was to have formally notified the company of what was not a fact—that the foundation was bad—and to have refused to build on the accepted foundation, except under protest. It seems to the writer that the simplest investigation of how unfairly these clauses can work out is amply sufficient to show the necessity of eliminating most of them and very carefully restricting the others.

Indemnity.

All agreements are elaborate in provisions to save the company harmless against any acts of the contractor during construction. These provisions are proper, provided the contractor is legally liable; they are wrong where the company withholds payments to force the contractor into settlements, whether proper or not. Many agreements recite that in the event that the company is a party to the action, the company may settle without the consent of the contractor and charge against him, together with such legal expenses as the company may choose to fix as its cost of defense. If the contractor, as an individual, is sued jointly with another individual, he must defend himself as best he can. There is no method by which he can recover the expense of defense, either against the party who sued or on account of whom he is sued.

The writer can see no fair ground why the company should be more favored in the case of construction contracts than in any of its other agreements where it takes its chance according to the general law. The fair principle is that, if the railroad pays the contract price, it should get the goods; if the contractor incurs liability, then, by agreement, he should indemnify the company against loss, and the obligation should end there. In accepting the

contractor, the company should consider his ability to save it harmless, just as it considers and accepts his ability to perform the work. If the company is sued jointly with the contractor, it may either let the contract or defend, looking to his satisfying any decision, or, if it elects to defend also, it should do so at its own expense, as it would in any other action.

POWER AND AUTHORITY OF THE ENGINEER, AND OF THE COMPANY.

The following extracts are from current specifications:

New York, New Haven and Hartford R. R.—"Right to change line or grade. * * * Should change affect cost of doing work, engineer shall determine price to be paid either above or below, so as to do substantial justice between the parties. * * * Work to be done under direction of engineer; his decision of the true construction and meaning of specifications and drawings final. * * * Contractor shall not sublet. * * * Company reserves the right to suspend, to close and settle up. * * * The cancelling shall not entitle the contractor to any claim for damages. * * * Should contractor be delayed by other contractor, by stakes, damage by fire, etc,. time shall be extended."

Erie R. R. and Baltimore and Ohio R. R.—"Quantities and disposition of excavation may be changed by alteration in grades, curves, or alignment. * * * If by such changes work is made more or less expensive, contractor shall have such allowances or deductions therefor as engineer considers just. * * * Contractor shall commence, prosecute and complete under direction of the engineer, who shall have power to direct the application of the forces; to change beginning and ending point of sections; to order the forces increased or decreased. * * * If methods or appliances appear inefficient, engineer may order the contractor to increase and improve. * * * Should right of way not be procured where contractor desires, he shall distribute his forces at other points without any claim for damages. * * * Contractor shall not sublet. * * * Engineer may make allowances he deems just for loss or damage to the contractor, resulting from right of way or other delays of any kind occasioned by the company. * * * Engineer shall have the right to regulate wages. * * * Contractor agrees to do work to satisfaction of engineer. * * * The classification of all excavation, masonry, etc., shall be made by the engineer; decision in regard to same shall be final and binding. * * * The company shall have the right at any time to suspend or annul the contract; such shall not give any claim for damages."

Norfolk and Western R. R.—"In case delayed through negligence or incompetence of a contractor for other work, no claim

against the company shall be made. * * * When this agreement is completely performed, performance accepted, certified in writing by Chief Engineer, final estimate shall be paid. * * * Such final estimate shall be conclusive unless reversed or modified by the president of the company upon appeal by either party. * * * Contractor shall not assign or sublet * * * Right to make any alteration in location, line, grade, plan, form or dimensions. * * * No claim for damages, on any ground whatever. * * * No compensation to contractor for hindrances and delays, but extension of time, provided contractor gives notice in writing. * * * Company reserves the right to suspend, terminate or restrict. * * * No claim for consequential damage or anticipated profit or damage of any kind. * * * All questions, differences or controversies in any way whatever pertaining to said work shall be referred to Engineer, and his decision shall be in the nature of an award, final and conclusive upon both parties, unless reversed or modified by the president, and compliance on the part of the contractor with every decision of the engineer, shall be a condition precedent to the right to receive any payment hereunder."

"Big Four."—"By failure to secure right of way, company is not liable for damages, but gives extension of time. * * * Engineer at liberty to make any changes. * * * Provisions of this contract apply to all changes. * * * Contractor shall prosecute work in such manner, at such times and points as engineer shall direct. * * * No portion of the work to be sub-contracted. * * * Final estimates upon the full completion, to the satisfaction, approval, and acceptance in writing of the engineer."

Chicago, Burlington and Quincy R. R.—"No damages from default of the company, but extension of time. * * * Engineer may make changes. * * * Addition or deduction to price to be made as engineer deems just and equitable. * * * Final estimates including quantity, quality, classification and price, shall be subject to revision and adjustment by Chief Engineer. * * * Company has the right to terminate contract on giving final estimate to date. * * * To prevent disputes or misunderstandings between the parties hereto in relation to matters of fact, but not of law, the engineer is hereby constituted and appointed the umpire to decide finally, his decision as to the quality, character, kind and classification to be in the nature of an award, final and conclusive."

Missouri Pacific Ry.—"No damages from any default of the company. * * * All provisions of contract to apply to changes. * * * Prosecute work as engineer shall direct. * * * Work shall not be sub-contracted. * * * Final payment upon the full completion to the satisfaction, approval and acceptance in writing of the engineer. * * * Company has right to suspend, or re-

duce force. * * * After suspension, company can order work resumed. * * * No claim for damage. * * * Engineer shall be, and hereby is made, constituted and appointed, the sole arbiter to decide all questions and matters, and said engineer shall determine and set forth in the final estimate, the quantity, character, kind and classification, under the contract, and his decision and determination, as to any and all matters, shall have the force and effect of an award, and shall be final, binding, and conclusive at all times and places."

Great Northern Ry.—"Contractor agrees not to relet. * * * Work at such points as engineer directs. * * * Engineer made umpire to decide all matters arising or growing out of the contract. * * * Company has right to stop any of the work or diminish force, no claim for damages. * * * Right to make changes, but price to be paid per cubic yard shall cover the risk of any change to the disadvantage of the contractor, and he shall have the benefit of any alteration that may operate in his favor. * * * The decision of the engineer on any point or matter touching this agreement shall be final and conclusive. * * * Said parties waive any and all right of action, suit, or other remedy, in law or otherwise. * * * Final payment when the certificate and estimate shall have been furnished by the engineer."

Chesapeake and Ohio Ry.—"Executed under the direction and supervision of the engineer, or his authorized assistants, by whose measurements and calculations, quantities shall be estimated, and whose determination shall be conclusive. * * * Final estimate on engineer's certificate that the whole work is completely and acceptably finished within the time specified. * * * Contractor shall not sublet. * * * Right to make any alteration in location, line, grade, plan, form or dimensions. * * * No claim for anticipated profits on work, altered or dispensed with. * * * Nothing construed into liability for damages from hindrances and delays, but contractor shall have extension of time. * * * All questions, differences or controversies shall be referred to the engineer; his decision final and conclusive to both parties."

The foregoing extracts are sufficiently illustrative of the powers stipulated for the companies in their construction agreements.

The powers claimed on the average may be summarized as follows:

Contractor to do the work where and when the engineer shall direct, whether the procedure is, or is not, a reasonable one in economical organization, and whether or not the procedure is fair.

Where the company is in default from any cause, the expense shall be borne by the contractor, his relief is in extension of time,

provided he gives notice and the engineer considers the point well taken.

The contractor shall equip his work with such forces and appliances as the engineer shall direct. In case he does not, the company holds the right to employ the force and charge the expense; to annul the contract in whole or in part; to seize the contractor's plant; and to withhold any unpaid sums of money which may then be due. The contractor's employees are subject to discharge by order of the engineer. A reservation of 10% is withheld from the contractor's payments in addition to withholding, by custom, another part at the discretion of the subordinate engineer. The company, of its own motion, without default on the part of the contractor, holds the right to terminate the contract at any time, to suspend the work, to hold the contractor to resume, with stipulated denial of the contractor's right, not alone to damage, but even for recovery of expense. The contractor must obey all orders of the engineer and accept his determination as final, at a time when the engineer holds the relation of an employee and agent of the company; the contractor knowing at times that the engineer has no detailed knowledge of the work, and that the information which he certifies as his final judgment is, in fact, the work of an assistant, with whom he may not be even personally acquainted.

Requirement that the company shall have the right to save itself in case of claims against the contractors; to make an *ex parte* examination, to settle the controversy and charge the contractor with the award and such expense as the company shall set, without consultation with the contractor, and without his acceptance. Requirement that the contractor shall exhibit complete receipts, showing that all accounts have been paid. Requirement that the contractor shall save the company harmless from every matter growing out of the construction.

Requirement that, before the contractor can get final payment for matters not in dispute, he shall accept the engineer's estimate as a total and release each and every matter and sign in full settlement, with a more drastic wording in some contracts; that the contractor shall have accepted the final, as handed out by the engineer, before the company shall have incurred any indebtedness to the contractor.

Requirement that, after the contractor shall have done work which is satisfactory to the inspector appointed for it, the work may still be condemned and required to be done over.

The stipulation in favor of the contractor is, that he shall have the right to accept without protest the sum of money the engineer shall say is due him.

It is safe to say that in no other business relation between men are such one-sided agreements customary; in no other relation is a man conceived to be clothed, by reason of a written instrument, in a mantle of infallibility, as is the engineer in customary railroad contracts. In political matters, some thinkers hold that an intelligent despot can give the most efficient government; so, in the case of the engineer, granting an untrammeled, industrious and able man, subjecting the contract to his exclusive decision may work out as the best arrangement all around. As far as the writer's observation goes, the average and general result is good, without much genuine offset; but every now and then there is an instance of gross tyranny and outrageous wrong under these powers. The delays, safeguards, and forms appropriate for a peaceful civilization would paralyze an active army. Railroad contract work requires somewhat of the army's autocratic directness of control, but the control should be within well-defined and reasonable lines.

The objection in a practical sense, however, comes, not so much from arbitrary or unfair use of the engineer's power, but from his carrying out, or being forced into carrying out, requirements which are too broad or are unreasonable, which he may have thoughtlessly included in his agreement, put there from mere copying of precedent, or at the suggestion of a legal department which considers only its side of the case. Ordinarily, these clauses are unnecessary. In spite of them, most engineers have to and do make fair adjustments, and settlement for the majority of work goes through with mutual satisfaction. With these clauses too strongly drawn, the engineer, in spite of a personal desire to be fair, may be forced by his company into an opposite policy, in accordance with the stipulations of the contract. In no class of cases is there greater real damage done than when organized work is suspended or stopped.

In the old days, when contractors' equipment was carts, scrapers and stock, the suspension of work was a serious blow. At the pres-

ent time the organization and plant for work is multiplied many times more than the requirements of twenty years ago. The expense, effort and time sunk in organizing, very often with special plant, has only a partial relation to the work which may be performed at a particular date. It is a general expense to prorate over all of it. Any suspension or stoppage cuts off the profitable part of the work, and where no compensation is made for the stoppage, the contractor is in effect robbed, whether it be by agreement or not, presuming that the contract was profitable in itself.

It must be further considered that the contractor, in making agreement for a given piece of work, has taken the risk, and if it can be shown that the uncompleted work would have been profitable, upon suspension of this work, he is legally and fairly entitled to that profit, subject to such offset as would be made by an earlier release of services. The no-damage clause offsets this or any other claim.

As the writer understands the obligation of contracts, in matters of measurement, classification, workmanship, meaning and application of specifications, and the like, which have to be decided by an expert, and for which the engineer is nominated by agreement as such an expert, his finding and decision will be held final in the absence of fraud. All other matters are at least open to court review. Therefore, a clear, fair contract interpreted by the engineer has a better chance to be upheld in its final than one which is unfair and extravagant in its stipulations in favor of the company. The time has about come for the companies to be willing to assume the risk of their own acts and plans, and not to saddle these risks further upon contractors.

In conclusion, the writer would say that the main thought in this whole discussion is: That a contractor and a company enter into an agreement for mutual benefit. Every matter not clear, subject to whim and opinion in its working out, unfair in its intent, or in the nature of a "strangle hold," is unfair to one side and reacts upon the other, and that the business of both parties is best served by a fair agreement.

Construction methods, throughout the United States, at least, are fairly uniform for like classes of material. There is, however, the widest variation in customs, requirements, specifications, and

general clauses for the agreements for such work. There is no valid reason why the agreements should not be standardized. The consideration and preparation of a standard form would be a very useful and important work for this Society, and of benefit to the greater number of its members, who have more or less to do with carrying out these agreements at one time or another. A standard form would not interfere with special modifications which might be necessary at times. These matters could be covered by special specifications, attached to the standard form.

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PAPERS AND DISCUSSIONS.

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LIBERATION OF AIR IN SIPHONS.

By Charles Anthony, Jr., M. Am. Soc. C. E.

Though siphons are appliances with which it is as well to have as little as possible to do, conditions may arise, especially when modifying pre-existing works, which compel their use. Under such circumstances, the designer is at considerable disadvantage through lack of data concerning the quantity of air which, under practical conditions, it is likely will be set free by water in its passage through a siphon.

Last year the writer designed and erected at East London, Cape Colony, the 12-in. siphon shown in Fig. 1.

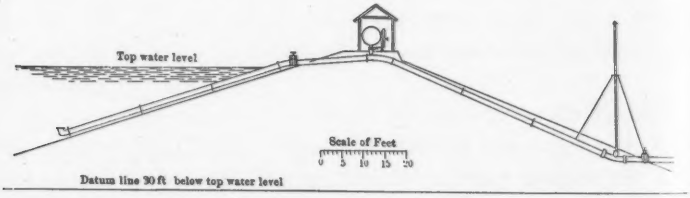


Fig. 1.

Before leaving Cape Colony he had not time to carry out, as he had intended, a series of experiments with the object of ascertaining the quantity of air liberated under different conditions, as

*This paper will not be presented at any meeting, but written communications on the subject are invited for publication with it in *Transactions*.

regards amount of negative head, temperature of water, amount of dissolved gases, and quantity of water passed, with the object of framing a formula which would take into due account each of these factors; yet the following results of the only experiment effected may, in view of the entire lack of data on the subject, be of some little service.

12-in. Siphon Over the Amalinda Embankment.

Air vessel charged February 12th, 1906, level of water inside	=	419.50
Air vessel empty March 22d, 1906, level of water inside	=	415.50
Capacity of air vessel	=	650 gal.
Quantity of water supplied during above period of 39 days, 39 × 359 000, approximately	=	14 000 000 gal.
Level of water in reservoir, February 12th, 1906	=	404.50
Level of water in reservoir, March 22d, 1906	=	409.50
Mean level of water in reservoir, during period of 39 days	=	407.00
Mean level of water in air vessel during period of 39 days	=	417.50
Quantity of air liberated within air vessel during period of 39 days, reduced to atmospheric pressure, $\frac{650\,[34 - (415.50 - 409.50)]}{34}$	=	535 gal.
Air liberated, in percentage of water supplied, $\frac{100\% \times 535}{14\,000\,000}$	=	0.0038%
Under a mean vacuum of 417.50 — 407.00	=	10.5 ft.

This experiment indicates that water containing the quantity of dissolved gases ordinarily found in impounding reservoirs in South Africa, in latitude 33°, under a mean temperature of about 70° fahr., that is, some 4% by volume, when passed at the rate of about 360 000 gal. per day, through a 12-in. siphon, under a negative head of 10 ft. 6 in., liberates, approximately, 0.00004 of its bulk of air, at atmospheric pressure.

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RECENT PRACTICE IN HYDRAULIC-FILL DAM CONSTRUCTION.

Discussion.*

BY MESSRS. WILLIAM L. BUTCHER AND T. G. DABNEY.

Mr. Butcher.

WILLIAM L. BUTCHER, ASSOC. M. AM. SOC. C. E. (by letter).—One point brought out by Mr. Herschel, although having no particular bearing on the matter of hydraulic-fill dams, seems to demand some comment. Speaking of the fallacy of supposing that filaments of water move in straight lines, he says:

"To this day the outlet gates of reservoirs for a domestic supply of water are placed at several elevations for the alleged purpose of enabling different 'layers' of the contained water to be drawn, whereas everyone knows, or by reflection may know, that water is as likely to reach such an outlet from above, or from below, or from any direction bounded by a hemisphere within the reservoir. * * *"

Inasmuch as practically every reservoir of any considerable size has the above-mentioned feature incorporated in its design, the question of its utility is a matter of some moment. While Mr. Herschel's contention would doubtless be true if the water in an open basin were of uniform density throughout its mass, there is an abundance of experimental data to prove that such is not the case.

The temperature changes with the depth and the season, thus

* This discussion (of the paper by James D. Schuyler, M. Am. Soc. C. E., printed in *Proceedings* for October, 1906), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

producing a varying density which gives rise, in deep ponds, in the more northern latitudes, to the well-known phenomena of the spring and fall overturn, during which the water from the bottom is brought to the surface, and *vice versa*. Furthermore, chemical analyses show that during seasons of more or less uniform temperature, the water becomes stratified, the organic matter in the bottom "layers" rapidly exhausting the oxygen in the water and producing foul conditions which remain until a change in season and temperature causes vertical circulation. Mr. Butcher.

Of course, the wind is a disturbing factor to ideal stratification, but an examination of the weekly temperatures of a number of reservoirs indicates that even where the maximum depth is not more than 20 ft., the water of least density is on top for a large proportion of the time. Therefore, there is apparently a very practical reason for designing outlet gates so that the water may be drawn from any desired level; and, under normal conditions, water would be drawn from that level and no other.

T. G. DABNEY, M. AM. SOC. C. E. (by letter).—The writer has read this paper and Mr. Herschel's discussion with much interest. Mr. Dabney.

In his observations concerning the design of the great Gatun Dam as projected, Mr. Herschel, to the writer's apprehension, appears to have fallen into a fallacy in endeavoring to point out what he regards as a fallacious idea in the minds of the designers of the dam.

Mr. Herschel objects to the extension of the base of the Gatun Dam ½ mile down stream, and insists that the base width should be limited to the proportions adopted in common practice for reservoir dams, with an impervious "core-wall" extending down to bed-rock beneath the dam foundation.

It is not the writer's purpose to undertake to justify the design of the Gatun Dam as a whole, not being in a position to pronounce upon it intelligently; but the particular objection made by Mr. Herschel appears to be based upon an erroneous conception on his part. Apparently he has neglected consideration of the particular conditions that controlled in the adoption of the plan proposed, namely, the presence of a mass of more or less permeable material—clay, sand and gravel—upon which the dam must rest, which is represented as of such great depth as to forbid the introduction of the usual "core-wall" down to bed-rock.

It is certain, then, that under a head of 85 ft. a considerable volume of water must be forced through the permeable medium underlying the dam, to control which the extension of base was designed. It is difficult to understand upon what ground Mr. Herschel assumes that this extension of base was adopted on the theory that the underground water would move only "in a direction parallel to the surface of the down-stream slope of the dam which has been described, or in a nearly horizontal direction."

Mr. Dabney. On the contrary, the very means designed to control the flow, namely, placing a great mass of earth over a wide space behind the dam, is obviously intended to combat the tendency of the water to escape in a vertical direction, and in full recognition of the rather elementary argument that water must flow along lines of least resistance.

The underground water when forced under hydrostatic pressure through the medium beneath the dam, must meet with a cumulative resistance to its horizontal movement as it proceeds further from the source of pressure; and, if prevented from escaping upward by a resistant body of earth, must reach a point at such a distance from the source of pressure that resistance to its further passage will counterbalance the velocity head, where further movement must cease; which point, in theory, should mark the limit of extension of the base of the dam.

The upward pressure must be greatest in the region next behind the axis of the dam, and here the superposed earth is thickest. Proceeding away from the central axis, both the hydrostatic pressure and the thickness of the opposing earth prism are proportionately diminishing, until a common point is reached where, theoretically, both these factors become zero. Under these conditions, there can be no flow of water "parallel to the down-stream slope of the dam," nor horizontally, nor otherwise, but all movement must cease, and the body of underground water must become stationary, or have so little energy of motion as to become negligible for practical purposes.

The attainment of this condition seems to have been contemplated in the design of the dam, and whether the requirements outlined above have been fully met by the plan proposed is the only question involved, in so far as the sufficiency of the dam alone is to be considered.

In the writer's experience as a levee engineer on the Lower Mississippi River, it has been found expedient, as well as much cheaper, and quite effective, to cover treacherous areas behind levees with water instead of earth.

The Mississippi River levees, in many localities, are underlaid by thick sand strata, of very permeable character, which are usually overlaid by several feet of tenacious clay, locally called "buckshot." These sand beds become fully water laden during flood stages of the river, and, not infrequently at such times, it happens that, under hydrostatic pressure, formidable eruptions occur behind the levees, in the form of dangerous "boils" or fountains, with alarming displacement of sub-surface material, culminating in some cases in a "blow out," and collapse of the levee.

The usual mode of combating this danger during floods is by building temporary "cisterns" or pools, with earth-filled sacks,

around the erupting crater, ponding the water over the orifice to a depth of several feet. By this device the velocity head is reduced, and, at the same time, the dead "water cushion" over the "boil" stops the displacement of solid matter below the surface of the ground. Mr. Dabney.

The writer has invoked this principle quite generally, by building permanent "sub-levees," around such treacherous expanses, and in cases where the inclosed basins embrace several acres, the process of filling them with water when under flood pressure, is hastened by the use of siphons placed over the levee. In one such case a wide channel is traversed by a large levee, the Hushpuckena Bayou, which at that point is 1 000 ft. wide. The flood head of some 30 ft. of water is distributed between the main levee and two sub-levees in series, the latter located across the channel about 400 and 1 500 ft., respectively, below the main levee, narrow channel widths being selected for these locations.

By this means the alarming symptoms of foundation instability are completely controlled, and the situation is rendered secure; and in all similar cases the results have been entirely satisfactory.

The sub-levees are provided with suitable spillways, and also with sub-drains to empty the basins after the floods subside.

The suggestion presents itself that the same principle might perhaps be invoked profitably, under favoring conditions, to afford security to doubtful foundations of reservoir dams; such favoring conditions being facilities for covering the eruptive area below the dam, in either the bottom or banks of the channel, with any required depth of water and to any desirable or necessary distance below the main structure, either in a single pool, or a series with diminishing depths and surface elevations, each separate structure being proportioned to resist only the head it has to carry, with a considerable factor of safety.

Whether or not this principle can be applied to other situations, the writer has found it indispensable for the security of his own levee lines, where instability of foundations cannot be corrected by other means.

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ADDITIONAL INFORMATION ON THE DURABILITY OF WOODEN STAVE PIPE.

Discussion.*

BY MESSRS. ANDREW SWICKARD, A. M. HUNT, L. J. LE CONTE AND T. CHALKLEY HATTON.

Mr. Swickard.

ANDREW SWICKARD, ASSOC. M. AM. SOC. C. E. (by letter).—If this paper brings out a thorough discussion of the durability of wooden pipe, as affected by general and local conditions, the profession will have been benefited. It is to be hoped that the discussions will be more than mere statements of the condition of the materials of which any particular pipe is constructed. Such statements are well enough as far as they go, but the writer believes them to be comparatively without value unless the circumstances and conditions, both general and local, which have brought about or influenced the deterioration of the pipe, are considered in connection with them. This is true of any kind of pipe—cast-iron, riveted steel, or wood. It is well known that iron pipe gives good service under some local conditions and exceedingly poor service under others. That this is also true of wooden pipe is shown by the fact that the durability of the many pipe lines which have been installed is not dependent upon the number of years they have been in use. Different lines built of the same kind of wood, but in widely separated localities, vary greatly in length of life, as do different parts of the same pipe line. There are always reasons for these differences, and a knowledge of such reasons is what is most desired by the profession. The fact that the con-

* Continued from December, 1906, *Proceedings*.

Mr. Swickard.

dition of the Astoria wooden pipe line does not compare at all favorably with that of many others, which are much older, suggests that there must be local causes which have brought about this comparatively rapid deterioration.

The author has made no effort whatever to account for the rapid deterioration of the parts of this pipe which have had to be renewed, notwithstanding the fact that he must know there are many wooden pipe lines, which are much older, and are in excellent condition; and that the reasons for the rapid deterioration of this pipe are what the profession most desires. The mere fact that any engineering structure has failed is of no value to an engineer unless he knows why it failed. No one is in a better position than the author to give the facts in this case.

There are but two conditions under which wood is absolutely decay proof: Absolute dryness, and constant submersion in water. The staves of a wooden pipe full of water are never in the former condition, and can only approximate the latter. As regards the degree of saturation, the staves in a pipe, therefore, are at some stage between the two extremes, and, as a consequence, are more or less subject to decay, depending upon the amount of moisture in the outer portion, which in turn is dependent upon the pressure.

If the moisture condition of the staves, alone, controlled the ravages of decay, then stave pipe built of wood of any particular kind or quality would last as long in one locality as in another, the pressure being the same. This is not true, and leads to the inevitable conclusion that there are other causes entering into the determination of the life of wooden pipe. These causes are almost entirely local, and generally cannot be controlled, but could probably be avoided or rendered less effective if known and understood. If local causes cannot be avoided, decay can be arrested somewhat by rendering the moisture condition of the staves less favorable by increasing the pressure. For example, had the Astoria pipe been located so that the portions which have had to be renewed (which are under a very low head) had been under a pressure equal at least to the "moderate" pressure referred to by the author, then the life of this entire pipe line would have been as long as that of Sections 2 and 3, or about 20 years. It is to be regretted that the author has not mentioned definitely what this "moderate" head is, above which the water pressure had little or no influence in preserving the wood. The only condition affecting the ravages of decay, that can be controlled at all directly, is the moisture condition, and, if this has little or no effect above a certain "moderate" head, it is desirable to know what this head is.

Decay is a vegetable growth, the branching threads of which

Mr. Swickard.

gradually spread themselves in all directions in the wood, converting the cell walls and the contents of the cells into food for their consumption. In order to thrive, this vegetable growth must have, among other things, some moisture. Air-dried wood does not contain sufficient moisture, and wood constantly submerged in water contains too much. Somewhere between these two the most favorable conditions will be found. Heat, to some degree (from 60 to 100° fahr. is most preferable), is necessary for a prolific growth of decay; too great a degree of heat will kill it, but intense cold will only arrest it. If the moisture and heat conditions are favorable, and there is an abundance of decaying wood scattered about to furnish the decay spores or seeds, new wood can be expected to begin to decay very soon and very rapidly.*

The Astoria pipe line is located for the most part in a dense forest of Oregon fir and hemlock. This region has an enormous rainfall which is distributed over a great part of the year. Throughout the forests of the Northwest there is much fallen timber, which is found in all stages of decay. The rainfall furnishes a favorable moisture condition, and, taken in connection with a moderate and even temperature, the fir logs decay rapidly, and, as a consequence, decaying wood is found all about. New wood in such a locality will show evidences of the deposit of decay spores within a very few days, if sought in the proper way. It is not to be understood that the new wood will show evidences of decay, but that the decay seeds have been deposited in the wood and are ready to grow. Favorable conditions, then, are all that is necessary, and the decay fungus will take root and thrive.

The arrowheads on the author's profile (Fig. 1) indicate that the repairs were confined to those portions of the pipe which were subjected to low pressure, and where the moisture condition for decay growth was most favorable. These parts are where it would be expected that decay would be most rapid. That, at these points, the pipe lasted for 10 years indicates that the low pressures prevailing produced moisture conditions which were not the most favorable for decay. Fir wood decays very rapidly, and pieces of timber similar in form to the staves used would decay beyond any possible use in 2 or 3 years, if left subject to the natural conditions that prevail in that region.

The writer is not willing to accept the author's statement that "water pressure, beyond a moderate head, has had little or no influence in preserving the timber." This is contrary to reason, and very probably the facts in this case, if carefully ascertained, would not bear out the statement. The quotation of Mr. Bergsvik, as to the future of the pipe, is relevant. Sections 2 and 3 will last 10 years longer, and it is very probable that the repairs mentioned

*Bulletin No. 10, U. S. Department of Agriculture, Division of Forestry.

as necessary 3 or 4 years hence will be confined mostly to Section 3, which is under a lower pressure than Section 2. It is to be regretted that the author has not gone into more detail in these matters, which are really the most important. Mr. Swickard.

There are other local conditions which very probably have exerted an influence in the deterioration of this pipe line. All the different kinds of wood available for pipe work have not the same characteristics that affect their durability. The wood from trees of the same species always varies in durability with localities and consequent changes in climatic conditions; even wood from different parts of the same tree varies. The most favorable conditions as to soil, moisture, light and heat, produce, in hard woods, the greatest degree of durability, but have the opposite effect in coniferous woods. The Astoria pipe line was built of Douglas spruce or Oregon fir, which are coniferous woods growing in the region about the Columbia River under most favorable circumstances. As a consequence, the fir lumber from this region would be expected to be less durable than that grown farther north, where the climate is more rigorous.

The author makes no mention of the fact that at least some of the most badly decayed portions of this pipe were at points where roots had grown down and entwined themselves about the surface of the staves. Brush or shrubbery, which grows rapidly and requires an abundance of water, will cause much annoyance along a wooden pipe line. About 3½ years ago about ½ mile of 24-in. wooden pipe was laid in Long Beach, in Southern California, a portion being in ground overgrown by willows (willow grows very rapidly and requires much water). Roots from these willows have covered the surface of the pipe, and the staves are deteriorating rapidly. The other portion of the pipe is in perfect condition. This mile of pipe was laid as an extension to about 11 000 ft. of pipe built in 1900. In making the connection between the old and the new portions, it was necessary to take apart about 200 ft. of the old pipe in order to lower the grade, and the staves of the older portion were so perfect that they were all rebuilt into the pipe. The decay of a portion of this line is caused by a purely local condition. To cite this case as a criterion of the life of wooden pipe, without some explanation of the prevailing conditions, would be unfair. The same remark will apply to the Astoria pipe.

The redwood pipe which the author refers to as being in no better condition than the Astoria pipe is very probably the 30-in. pipe built for the West Los Angeles Water Company in 1896 and 1897—the plant of the West Los Angeles Company has been transferred to the City of Los Angeles. One of the main troubles with a considerable portion of this pipe line is that it passes through

Mr. Swickard.

ground overgrown with willow brush; and where the roots entwined themselves about the pipe there was a rapid deterioration of the staves. The roots seem to reduce the wood to a condition different from that produced by ordinary decay. Causes of deterioration of this character are local, and, usually, can be avoided. Since 1898 this pipe has been full of water with the exception of 8 or 10 days each year during the past 3 years. Repairs were made during these 8 or 10-day periods, and certainly the time indicates that they were not extensive.

The importance of keeping a wooden pipe full of water at all times cannot be over-estimated. If a pipe is but partly full of water, even for a few months, decay, which otherwise might not have started, will begin. Wood once attacked by decay is predisposed to further deterioration, even if measures are adopted to render the conditions less favorable. The winter of 1897-98 in California was exceedingly dry, and the West Los Angeles Water Company did not have sufficient water to keep the 30-in. pipe, before referred to, filled. During the summer of 1898, it was found that decay had started at some points, and the company was put to considerable expense trying to keep the pipe full of water. The decay was of a kind that destroyed the staves very rapidly. In a comparatively short time in a few places the staves were rotted nearly through. This rapid decay was the more remarkable because redwood has greater durability than any other wood available for pipe work on the Pacific Coast.

The Southern California Mountain Water Company, at San Diego, had a similar experience with a line of 36-in. pipe, due to the pipe, or portions of it, being only partly full of water during an exceedingly dry and hot summer. The writer saw samples of staves, taken from this pipe, which had the appearance of wood subjected to high heat in the presence of a limited quantity of oxygen. The company recognized the fact that its troubles were due to avoidable causes, and has repaired this pipe. About 10 miles of 36 and 24-in. pipe have since been built as an extension of this line, and the company is planning to make another large installation of redwood pipe.

In 1890 the City of Cheyenne, Wyo., built about 9 000 ft. of pipe, using Oregon fir staves. The upper part of this pipe was never full of water, and, as a result, the top staves decayed rapidly, and a portion of the line—about 4 000 ft.—was replaced with sewer pipe. The remaining portion of the wooden pipe is not kept full of water all the time, but is still in operation; it is in an unsatisfactory condition. This is an instance where wooden pipe should not have been used.

A decaying fence post will show most evidence of rot at or

just below the surface of the ground, with a gradual decrease downward, while it will be absolutely sound above the ground. This may also be expected to be true in the case of wooden pipe, where it is built with portions above and under the ground. Mr. Swickard.

All forms of construction which remove a portion of a stave from immediate contact with the water should be avoided. In making junctions between wooden and iron pipe, the method of putting the iron inside of the wood should be avoided. The 10 or 12 in. of stave-lap on the outside of the iron pipe is almost sure to give trouble in a comparatively short time. It is best to make a special iron hub to receive the end of the wooden pipe, and caulk the joint with oakum and lead in a manner similar to that used in making joints in cast-iron pipe.

When, for any reason, decay attacks a pipe which is subjected to considerable pressure, there does not seem to be any reason why staves at the bottom of the pipe should not decay, as well as those at the top. If the head on the center of the pipe is so slight that the difference of pressure between the top and bottom is comparatively large, one would naturally expect decay to take place in the upper staves first and gradually extend to the lower ones. That sound staves are found contiguous to decayed ones is due to the difference in the durability of the wood of different trees of the same species, and also to the difference in the durability of staves cut from the same tree. Staves taken from the butt cut of a coniferous tree are always more durable than those taken from the upper cuts. It is not practicable to obtain lumber cut from the butts of trees only, except in limited quantities and at considerable extra expense.

If the Astoria pipe line was the only wooden pipe line that had ever been built, or the oldest, it would naturally be taken as a criterion of the life of this class of water conduit. There are many pipe lines, which were built a good many years before the Astoria line, which are in good condition to-day. The first wooden pipe built strictly in accordance with modern construction was installed by the Denver Water Company. Some of its oldest pipe was installed about 25 years ago. This company is undoubtedly satisfied with its experience, for, at the present time, it has under consideration the installation of about 12 miles of large-sized wooden pipe. This will probably be built in 1907. It is fair to presume that the numerous installations made in recent years at points not far distant from Denver, and also the projects now under consideration in that region, which include the extensive use of wood pipe, are due directly to the fact that the early installations have proven highly satisfactory. To select one of the oldest wooden pipe lines, which has proven satisfactory, as an example of what

Mr. Swickard. might be expected from such pipe in any locality, without reference to the conditions that made a long life possible, would be manifestly unfair; to go to the other extreme, would deserve the same criticism.

The author neglected to mention that the Astoria Water Commission installed 500 ft. of redwood stave pipe in connection with the water system. This was built in 1900. Where the old pipe has been rebuilt, redwood staves have been used. It would be interesting to know whether the present condition of the 500 ft. of redwood pipe, compared with that of the fir pipe when it was of the same age, influenced the Commission to use the redwood staves. Redwood railroad ties last more than twice as long as fir ties, as far as decay is concerned, and it is probable that this same ratio of durability would exist in all cases of similar conditions and circumstances. It seems fair to presume that, had redwood been used instead of fir, the life of those portions of the pipe which have been repaired would have been 20 years instead of 10, and that the life of the remainder, especially those portions under a moderately high pressure, would have been 35 or 40 years.

Since preparing the foregoing, the writer has received information, from a most reliable source, to the effect that the air-valves referred to and indicated on the profile of the pipe line (Fig. 1), are merely check-valves. These check-valves do not allow the entrapped air to escape, and are only intended to let air into the pipe—if for any reason (by design or accident) the water is suddenly allowed to escape at a lower point—and to allow the air to pass out when the pipe is being filled.

As the air-valves represented are not such in the sense that they will allow the air to escape while the pipe is under pressure, it is certain that air accumulates at the high points on this pipe line. This accumulation of air, without doubt, has had the effect of producing a moisture condition in the staves at these points, which is more favorable for decay growth than would otherwise have existed.

It will be noted that, while most of the repairs are indicated as having been made at the high points of the pipe, none (with perhaps one exception) are indicated as having been made at points where stand-pipes are located. This is a significant fact, and seems to indicate very clearly that the entrapping of air at the high points has been more than an ordinary factor in hastening the decay that has taken place.

Mr. Hunt. A. M. HUNT, M. AM. SOC. C. E. (by letter).—Within the past year the writer has had occasion to inspect three short lines of wooden stave pipe installed in connection with power plants on the Truckee River, in California.

Mr. Hunt.

One is a 9-ft. pipe, about 1 800 ft. long, supplying water to operate a paper mill at Floriston, Cal. It is of the usual construction, having redwood staves about $3\frac{5}{8}$ in. thick. The pipe is mainly above the surface of the ground, the lower half of its circumference being bedded with earth and stone spalls. It is under a pressure varying from about 16 to 35 ft. It was built in 1898 and has been in continuous use ever since, being kept full of water. It shows no evidence of decay of staves or corrosion of bands.

The writer had occasion to bore through the pipe, to make velocity measurements, more than a year ago, and, although the outside of the wood was dry, on getting below the surface, it was found to be moist.

There are two other lines of 6-ft. pipe just below this line, supplying water to the wheels of the Truckee River General Electric Company. These lines were built in 1899, and the staves, the writer thinks, are of Oregon pine. Up to the present time, the pipe has shown no evidence of decay. It is supported in the same manner as the pipe first mentioned, the upper half being exposed. The pressure varies from 6 to 65 ft.

Mr. Le Conte.

L. J. Le Conte, M. Am. Soc. C. E. (by letter).—The profession is greatly indebted to the author for boldly giving the results of his experience. Such cases bring out most important facts, which ought to be known, and the sooner the better.

The writer has not had much direct experience with pipes of this class, but has always held the opinion that they are good, cheap and durable, and entirely suitable for light pressures. It now seems that experience along the entire Pacific Coast goes to show that the life of wooden stave pipe, when buried in the ground, is frequently only from 10 to 11 years. A closer observation leads to the conclusion that the chief danger, as far as known, lies in loamy soil, or where the back-filling contains vegetable mould. Apparently, it makes no difference whether the ditch is deep or shallow, the pipe under heavy or light pressure, or whether the staves are of pine or redwood—the results seem to be about the same.

Nevertheless, there are certain places along the same pipe line where for some reason the pipe is apparently all right. The exact nature of these conditions, in any case, and, of course, their full extent, are as yet largely unknown. It remains for future experience to bring out and develop the facts clearly. The writer learns, from good authority, that the supply-main feeding a certain section of Los Angeles and the Soldiers' Home is of redwood stave pipe some 30 in. in diameter. This pipe line is now about 11 years old, and is reported to have practically gone to pieces. It is entirely proper, however, that the facts in this interesting case should be submitted by the City Engineer of Los Angeles, which no doubt he will do.

Mr. Le Conte. The Oakland Water Company has some wooden stave pipe leading from the flowing wells at Alvarado to the sump at the pumping station. This piece of pipe is laid in wet, soggy ground, and one would naturally suppose it would be all right in such soil. It has been lying there for about 11 years, and examination shows that it, also, has all but gone to pieces.

Wherever this pipe is laid underground, therefore, there will always be a certain doubt as to its probable durability. It is likely to rot out, in places, in 11 years, depending upon the character of the soil in which it is laid. As far as known, vegetable mould is one of the active agents which seem to hasten decay.

In view of the many uncertainties connected with the probable life of such pipe, when laid underground, it would seem to be advisable, wherever practicable, to lay it on top of the ground, where it is known to have good lasting qualities. In a great many cases this can be done without objection.

Mr. Hatton. T. CHALKLEY HATTON, M. AM. SOC. C. E. (by letter).—This is a very important subject for the several reasons that the prices of steel and cast-iron pipe have advanced to such a point that many small cities and towns are prevented from carrying out much needed improvements to their present water supplies; and also from the fact that the demand for cast-iron pipe at present is so great that, even though the municipality is possessed of ample funds, such pipe cannot be secured in any great quantity in less than 6 or 9 months. The costs of lead and labor have also advanced very much during the last year, and thus it becomes almost mandatory to seek some material to take the place of iron and steel.

For these reasons alone, the writer, during the past three years, has investigated in considerable detail the merits of wood pipe. This investigation has covered much of the irrigation work in the West where continuous wooden stave pipe has been used for many years, and several of the municipal and industrial plants where both continuous and machine-made wooden stave pipe have been in use for at least forty years. It may be of some interest to present briefly the results of these investigations.

Continuous wooden stave pipes, where bruised, either in the handling or by cinching the bands too tightly, were found in most instances to have suffered some decay where the pressure was moderate—less than 50 lb. This was also found to be the case where the longitudinal joints were wide at the outer surface and the contact not good, or at the end joints, which were not in close contact, or where a dry crack existed in the end of the stave before it was built into the pipe. The cause for this is very clear. Where the wood fibers do not have natural and direct contact

throughout, and recesses are left, the water pressure from within is not continuous, and perfect saturation does not result. Thus lodgment is found by the organisms which destroy the wood, and its decay is inevitable. To avoid this, the writer believes that the outer surface of the wood should be thoroughly coated with some protective material which will prevent the entrance of these organisms, and that this coating should be applied as soon as the wood comes from the planer, thus preventing the organisms from finding a home. If it should be applied after the wood has been exposed to the atmosphere, these organisms will work just as well under the coating. This fact is apparent to anyone who has closely observed the life of timber under various conditions. Mr. Hatton.

These investigations did not disclose any facts such as Mr. Adams describes in his Conclusions 5 and 6, as far as contact with vegetable matter was concerned. In many places where the pipes were uncovered the material in contact therewith was at least 50% vegetable matter, and no evidence of decay was found, although the pipes had been in constant use from 8 to 14 years. It was found, however, that where the top of the pipe was only partly covered, or had but a few inches of dry earth over it, a dry rot had extended to a depth of from $\frac{1}{8}$ to $\frac{1}{4}$ in., but as soon as the point of constant saturation was reached, the wood was sound.

The greatest defects which the writer found in the continuous wooden stave pipe were in the end joints between the staves, due to the saw kerf of the two ends not being exactly in position, so that, when the metal tongue was inserted, the inner or outer edge of one stave was a little higher or lower than that of its neighbor. Another marked defect was in the durability of the steel bands. These bands are from $\frac{1}{4}$ to $\frac{3}{4}$ in. in diameter, are bent to a circular form, coated with a preservative of asphaltum pitch or material of similar character, and are supposed to be free from oxide when placed on the pipe. As a matter of fact, however, the writer saw delivered upon the work hundreds of these bands, which had been exposed to the weather for sufficient time to give them a thick coat of rust. In this condition they were dipped into a bath of the protecting material, thus covering the rust but not stopping its deteriorating effects by any means. In many instances the threads at one end of these bands were badly rusted, not having been coated; and in most instances it would have been dangerous to move the nut, as stripping would have doubtless occurred.

The writer's investigation of continuous wooden stave pipe led him to believe that there were too many uncertainties in its manufacture; that, while the wood would undoubtedly outlive steel, and perhaps cast iron in many instances, yet its construction must be necessarily left to irresponsible, partly unskilled workmen, who

Mr. Hatton. in many instances had to prosecute their work under the most unfavorable conditions. For these reasons he turned his attention to a study of machine-made wood stave pipe.

Here he found a wooden pipe being made of the same kind of materials as the continuous wood pipe, all made and banded together by automatic machines run by capable workmen, and every stave and band, and the coating and all workmanship entering into the construction, open to inspection under the most favorable conditions. The inner and outer surfaces of the pipe are cut to fit a circle; the steel bands, of either continuous band steel of any width required by the pressure to which it was to be subjected and of about No. 16 gauge, or of steel or copper wire of any gauge demanded, while bright and free from rust, are run through a bath of warm asphaltum pitch and then wound spirally upon the pipe, carrying with it a heavy coating of the pitch, thus preventing the inner surface of the band from coming in direct contact with the outer surface of the staves. Each end of the band is well secured by a double band around each end of the 7 or 8-ft. section, the length in which the pipe is usually made. As soon as the banding is completed, the section of pipe is run over two rolls moving through a warm bath of the asphaltum pitch, thus coating the outside surface of the wood and bands with a full protective coating of from $\frac{1}{4}$ to $\frac{3}{8}$ in. in thickness. To prevent this coating from running, the pipe is immediately rolled in saw-dust, which adheres to the coating and prevents it from being knocked off or abraded in handling. An extra coating can be readily applied to each section by repeating the operation, and, in all instances occurring under the writer's notice, this covered the bands and pipe to a thickness of nearly $\frac{1}{2}$ in. This coating, as soon as cool, becomes very tough, and can only be removed by a chisel. It is not injured in shipping and handling, and the pipes come upon the work in as good condition as when they leave the factory.

These machine-made pipes, as made in the West by the Washington Pipe and Foundry Company, are provided with a wood stave coupling about 8 in. long, which fits over the spigot end, said spigot end being driven into it, making a strong and water-tight joint. The machine-made pipe, as made by the Wyckoff Companies, of Elmira, N. Y., differs from the above in having a tenon, 4 in. in length, on one end and a mortise of the same depth on the other end. The latter is in the form of a truncated cone, so that when driving the pipe home the joint becomes tighter the further it is driven. The inner and outer surfaces of the pipe, when formed by this method, are continuous throughout, that is, there are no projections, and the swelling of the wood when saturated by the water makes the joints as good as the body of the pipe. These

Mr. Hatton.

pipes can be made of any diameter from 6 to 60 in., to withstand any pressure up to 300 lb. per sq. in., according to the banding, and can be laid by unskilled workmen in either wet or dry trenches.

The writer is now laying 4 miles of 24-in. Wyckoff pipe in Southern New Jersey to carry water from a reservoir to the Carney's Point plant of the E. I. DuPont Powder Company; and 800 lin. ft. of this pipe have been laid in a day, much of it in from 6 to 8 in. of water in the bottom of the trench. The jointing of the pipe is such a simple matter that the inspector, standing on the surface above the trench, can tell at a glance whether it has been properly done, as any change in alignment or gradient can be detected at once at the joint, because the two shoulders of the adjoining pipes must abut all around when properly laid.

When this work is completed, the writer hopes to present to the Society the results of experiments as to flow, costs, etc., which he is going to make. It may be stated now that the contracts let for the 4 miles of supply main show a saving of $53 130 over cast-iron or steel pipe for which preliminary bids were received.

The description of the manufacture of machine-made wooden stave pipe has been given in some detail because the writer knows of many members of this Society who have never had it brought to their attention and know nothing of its merits, and he hopes his investigations may help them to revise their future estimates, as he was glad to be able to do.

In investigating the durability of this machine-made pipe, the writer visited a number of places where it had been used for 30 years under a varying pressure of from 50 to 200 lb. per sq. in. Some of this pipe had been used for 8 years under a direct pumping pressure of 200 lb. per sq. in. Some lengths of pipe were shown which had been in service for 30 years and had been taken up to be replaced by the same make of pipe of a larger size. The wood was in an excellent state of preservation; the bands, while showing slight corrosion, were in good condition to reinforce the pipe; the asphaltum coating showed some deterioration on the outside, but that on the under side was in a good state of preservation. The pipe had been laid with about 4½ ft. of covering, the soil being gravelly clay with some quicksand.

The writer has received letters from the officers of twenty-five municipalities, water companies and industrial establishments where this pipe has been in use from 5 to 46 years, and in every case these officials testify to the durability of the pipe. In no case was an answer to his inquiries unfavorable, or indicating that the pipe was not perfectly satisfactory in every way.

Several years ago, while building a sewerage system in Wilmington, Del., the writer dug up some 300 ft. of wooden water pipe,

Mr. Hatton. buried some 8 ft. underground. This pipe was made of bored logs of white pine, was full of water not under pressure, and was sound throughout, although it had been laid prior to 1837—how long before that was not known. The joints were made by a tenon and spigot, and were in excellent condition. The logs had cracked in every case in two concentric rings about equidistant, and also at right angles to the axis at several points, no crack extending through the body of the pipe. Every pipe was in this condition. This season, while making some improvements to the streets of Salisbury, Md., some old corduroy road was dug up on the main street. The logs were of white pine, from 6 to 8 in. in diameter and were buried approximately 12 in. below the surface of the street, which was surfaced with oyster shells. These logs, of which there were a great many, were carefully examined, and were found to be in perfectly sound condition throughout.

The foregoing illustrations lead the writer to believe that wooden stave pipe when made of the proper material, namely, good soft white pine, Douglas fir, cypress or even red cedar, well selected, and free from dry or black knots, either air- or kiln- dried, free from cracks, well jointed and secured with steel bands protected from corrosion, will last, under average conditions, as long as cast-iron pipe; and the lasting qualities of steel are not in the same class.

The writer further believes that the life of the wood can be greatly increased by giving it a further protective coating of asphaltum pitch, and that the steel, iron or copper bands should be thoroughly covered with the same material, and therefore they should be of flat band-steel or wire. He also believes that machine-made pipes are more durable, as they can be inspected more carefully during manufacture, built by more skilled workmen, and can better be covered with protecting material. "The proof of the pudding is in the eating;" proof of the durability of wooden stave pipe is obtainable in all parts of the United States, and may be secured by any engineer for the asking.

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PAPERS AND DISCUSSIONS.

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THE NECAXA PLANT OF THE MEXICAN LIGHT AND POWER COMPANY.

Discussion.*

By Messrs. Edwin H. Warner, H. F. Labelle, F. G. Baum and J. D. Galloway.

Mr. Warner.

Edwin H. Warner, M. Am. Soc. C. E. (by letter).—Approximately ideal conditions exist in the plant designed and described by the authors—a high head, moderate length of penstock, cheap storage, and a market well within the limits of economical transmission.

The ideal of a practically uniform annual flow, doing away with seasonal storage, exists in but one plant on this continent,† except in cases of very moderate heads.

Table 1 shows the need of storage, and, since this need exists, it has cheapness to recommend it.

The authors' prediction of excessive floods has been confirmed during the present rainy season; a maximum flow of 5 280 cu. ft. per sec. for ½ hour occurred on August 13th; a flow of 3 720 cu. ft. per sec. for a similar length of time was observed on October 11th; the flow for 24 hours on each of these days approached very nearly the authors' maximum of 3 000 cu. ft. per sec. The conditions making possible these extreme floods were the complete saturation of the water-shed by 4 days' rain, and a fall of 6½ in. during the 24 hours prior to the dates mentioned.

* This discussion (of the paper by F. S. Pearson, and F. O. Blackwell, Members, Am. Soc. C. E., printed in *Proceedings* for October, 1906), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† "The Hydraulic Plant of the Puget Sound Power Company," by Edwin H. Warner, M. Am. Soc. C. E., *Transactions*, Vol. LV, p. 228.

Mr. Warner.

TABLE 1.—AVERAGE PRECIPITATION AT NECAXA, 1901 TO 1906, BOTH INCLUSIVE; AT CÁRMEN FOR 1906; AND TOTAL PRECIPITATION AT NECAXA FOR SIX YEARS.

Month.	Necaxa.	Cármen.	Month.	Necaxa.	Cármen.	Year.	Necaxa.
January..	2.66 in.	0.24 in.	July	21.81 in.	4.06 in.	1901	117 in.
February.	1.87 "	2.66 "	August....	15.20 "	13.54 "	1902	83 "
March	2.32 "	0.78 "	September	9.21 "	2.52 "	1903	101 "
April	4.28 "	3.39 "	October ...	11.78 "	12.40 "	1904	132 "
May	3.18 "	3.50 "	November.	4.71 "*	4.40 "†	1905	92 "
June.....	15.71 "	0.96 "	December.	3.28 "	4.40 "†	1906	92 "
						Total precipitation.....	617 in.
						Average precipitation, per annum.....	103 in.

* November and December, 1906, averaged from preceding five years.
† Average of preceding ten months.

The diversion of many small streams into the Nexaca Valley at low cost gives, with the large storage areas, a perennial supply equal to all possible demands for many years to come. Already the demand is approaching the rated output of the first installation now nearing completion.

The extension of the plant by a second installation, with a fall of 720 m. (2 341.6 ft.) between the Tezcapa and Los Reyes Dams (Fig. 1)* will involve an interesting development of large units at high speed, with the related problem of so nice an adjustment of sizes of intake, penstock and nozzles as to secure continuous operation. The pipe flanges (Fig. 3) deserve careful consideration. The writer confesses to a prior preference for riveted pipe in large sizes; but, having laid, full-bolted and tightened, 1 870 ft. of this pipe in 6½ days (three shifts of 24 hours each), it has his heartiest recommendation. The German shop work is admirably standardized, as must be the case where a misplaced gasket prevents the bolting rings taking the correct position, and localizing any leakage in the bolting. The pipes have generally a length of 9 m. (29.5 ft), and weigh, in the larger thicknesses, 4 tons each. To handle this pipe on 36 and 41° slopes (Plate XCIX)* and lay it in the confined space of a 13-ft. tunnel does not favor rapid work.

Whether a rubber gasket, under heavy pressure from side and edge, will rot or harden with time, is an open question. The writer is inclined to the latter belief. The one criticism to be offered with respect to this pipe is on the variation in the bolts; there are seven sizes of what may be called standard bolts, and three special forms, and as many sizes. These latter are necessary. The number of sizes of standard bolts, from practical considerations, could be materially reduced.

* *Proceedings*, Am. Soc. C. E., for October, 1906.

Mr. Warner.

The arrangement of gates in the vicinity of the upper end of the 30-in. pipes (Fig. 1, Plate CVI) is very elaborate, and while their number—eleven in all within a space of 20 ft.—is larger than usual, all possible contingencies are provided for. Motor-driven valves on the 30-in. pipes, operated from the power-house, would insure quicker closing than is now to be had, but the instantaneous action of the relief valves gives ample time for hand operation, except in the very remote contingency of a serious break in the pipe.

Mr. Labelle.

H. F. LABELLE, M. AM. SOC. C. E. (by letter).—The plant described in this paper has a great deal of interest for the hydraulic engineer, inasmuch as it contains many novel features of design. The large hydraulic-fill dam, the intake tower, the use of large lap-welded pipes in the lower parts of the penstocks, the introduction of square nozzles and, above all, the application of the impulse turbine to the operation of generators on a vertical shaft, are all points worthy of special attention.

The managers of hydraulic plants try to have the system of racks connected with their stations under their thumbs, so to speak. Racks are a fruitful source of trouble to superintendents of hydraulic stations, and the fight, at times, assumes important proportions. Various means are used to keep racks clean and prevent fluctuation of head; there are baffling walls, heating coils, steam, mechanical rakes operated by electric motors, zigzag racks, herringbones in combination with sluices and, of course, the ubiquitous man-rake. In the Necaxa plant the intake, fortunately, is placed in a large body of water, and, in proportion to the discharge of water, very little drift will come to it. Nevertheless, the designer has placed abundant protection, at the intake, against the entrance of floating matter into the penstocks. It is hard to see, however, how the inside screens can be cleaned in case they require it. Are they made in sections, and has special provision been made for lifting them? The writer would like to be informed regarding the operation of these screens and racks under various conditions.

It is believed that the branching of the penstocks, near the power-house, each branch supplying one or two generating sets, has originated in American practice; on this Continent it is not a new thing. In Europe, the turbines of two of the best-equipped high-pressure plants, one at Tivoli, near Rome, the other at Vallorbes, in the Swiss Jura (which, by the way, is said to have the most perfect and up-to-date electrical installation in Europe), are fed by a single line of pipe, and only recently the Kubel plant, near St. Gall, Switzerland, has duplicated its original penstock. The plant recently completed at Obermatt (supplying Lucerne) has also a double penstock in operation, with two additional pipes for future extensions.

Mr. Labelle. The use of lap-welded, flanged pipe of large diameter for penstocks is a comparatively recent innovation, both in Europe and America. This kind of pipe was used at Vallorbes, but with more commonplace flanges than those described in this paper. In case of accident to this kind of pipe, it is obvious that it is far easier to make repairs than with a riveted pipe. At the head of each of the 30-in. lines and just below the stand-pipes, the writer would have liked to see the installation of a butterfly, or other kind of valve, operated by a motor from the station switchboard, and designed to shut off the water in case of accident to, or bursting of, its appurtenant 30-in. line, thus saving the other lines from possible destruction, and preventing serious damage to the power-house.

Heretofore, the high-pressure or impulse turbine (in America commonly called the "Pelton" wheel) has been designed with a horizontal shaft, with very few exceptions, and this for turbines of the smaller sizes. The designs have carried one or more nozzles, the multiple nozzle being seldom used in Europe. In a few of the plants designed by Escher-Wyss and Company, the double parallel nozzle, operating two sets of buckets, is used, but in the majority of even the most recent European high-pressure plants, the old design is adhered to. The generating units of the Necaxa plant are radical departures in this respect, inasmuch as they show the combination of the impulse turbine and the vertical dynamo in new roles, the former on a vertical shaft, and the latter, which heretofore has been confined to low heads, operating a plant under 1 300-ft. head.

It is pertinent to state here that the two patterns of turbines used almost exclusively in Europe to-day—the Francis turbine and the Pelton machine—are of American origin. A few years ago European designers of turbines, and among them the firm of Escher-Wyss and Company, which represents the best practice in Europe, attempted to force the Francis reaction turbine out of its legitimate field, by applying it to high-pressure plants; the Pelton machine, however, soon showed its superiority in that field over all reaction outfits, and it is seen now in all the latest European developments running under a high head. Exception is to be made of the Tivoli plant, which has Girard turbines; improvements in that line, however, have been so rapid that the hydraulic plant at Tivoli is now almost old-fashioned. In 1903, of 108 turbines built during the year by Escher-Wyss and Company, only 3 were of the Girard type.

In the 18 or 20% which separates present efficiency in turbines from perfection, there is some 5 to 8% of frictional resistance between the moving and non-moving parts; this, in a large machine, constitutes a considerable loss of power. This resistance in vertical direct-connected sets is reduced considerably by the introduction

Mr. Labelle.

of oil pressure to support the moving parts, which are under about the same conditions as the rotating screen of a lighthouse, which floats and revolves on a body of mercury. In that way, friction is reduced to such a point that when the oil pumps are in operation, the rotor of a 1 000-kw. machine can be moved by one man. This has been done repeatedly in the Chèvres station, which supplies Geneva, Switzerland. For this and other reasons, given in the paper, this new turbine design should have a very high efficiency, and it is to be hoped that some record of the performance of the turbines described will be given by the authors in their review of the discussion.

The 4 000 voltage of the Necaxa generators is somewhat above the time-honored and quasi-classical 2 000 to 2 500 voltage commonly used in America, but it is still far below the voltages which have been used successfully in Europe for some years. Tivoli has been one of the pioneers in that line, the generators at that plant running at 10 000 volts, and this is also the line voltage. Other plants generate at 11 000 and as high as 20 000 volts. In America these high voltages have been accepted, at last; the new plant near Salisbury, S. C., on the Yadkin, will generate at 11 000 volts. The Anglo-Roman Electric Power Company, which operates the Tivoli plant, is so well pleased with this high voltage of generation that it is preparing to develop 5 000 h.p. above Tivoli, and is installing generators which will run at 30 000 volts; the current will be transmitted to Rome at that pressure, and then stepped down to 10 000 volts, so as to connect it with the old system.

Some years ago, hydro-electric developments were carried out without much concern about storage possibilities in the water-shed. If a stream had a fairly even discharge throughout the year, it was considered a good proposition; if not, it was regarded as of doubtful value, and no attempt was made to increase this value by storage. In sections where the rainfall is distributed evenly over the whole year, and where streams have more constancy of flow, storage, although always helpful, is not as important as in places where the rainfall is confined to one-half the year, as in certain parts of the tropics and in semi-arid countries, where, at the end of the dry season, streams have dwindled to nothing. Even if the yearly rainfall is abundant, it occurs mostly during one part of the year, and, therefore, the streams fluctuate too much in quantity to be of any use for power purposes. Storage, when practicable, and where the cost of reservoirs does not bring the enterprise outside of proper limits financially, can improve a power proposition wonderfully, and change an otherwise valueless stream into a valuable property.

Although this statement may appear self-evident to many, still

Mr. Labelle. there are people who wish to be considered wise and well-informed on these matters, who refuse to see any advantage in storage. A few years ago, it is true, storage reservoirs in connection with hydro-electric plants were not a fashionable combination. Works were designed on the basis of minimum or normal flow, and at some plants as much as 75% of the yearly run-off went down the river without being utilized. Lately, however, at least one section of the country is making for storage. Having outgrown the capacity of their plants, or having tired of paying exorbitant prices for coal used in their steam auxiliaries, the electric power companies of California have begun to investigate storage; as their country is topographically well adapted to reservoir building, it is to be expected that this phase of power development will soon come into prominence on the Pacific Coast. It is to be feared, however, that the reservoir sites will cost a great deal more now than if they had been purchased at the start, and if storage considerations had been included in the original designs.

The map (Fig. 1) shows the importance which the designer has given the question of storage. The proper conditions, being found, have been quickly taken advantage of. Without storage the combined minimum flows of the two rivers would have produced about 12 000 h. p.; with reservoirs (and in dry years there is more than 15 000 000 000 cu. ft. of available rainfall to fill them), the average flow can be used, producing about 50 000 h.p., at probably no greater cost per kilowatt of output delivered than with the smaller development. Further, the plant has the advantage of obtaining its storage from several reservoirs, which can be built successively as the output requires it; besides, it has at its command auxiliary streams which may be utilized when necessary.

What the writer has just stated about auxiliaries to hydro-electric plants must not be construed as a wholesale condemnation of them. This question of auxiliaries is a complicated affair which has not been completely sifted out in America, and, until lately, it has been completely neglected in Europe. Whether auxiliaries should be adopted at the start, their adoption postponed to some future time, or neglected altogether, are questions of much moment for designers and promoters of works dealing with the transmission of hydraulic power.

Dr. Perrine* truthfully describes the present state of this matter in America, when he says:

"After all has been done that is possible in obtaining the best possible storage and in selecting the most satisfactory customers, it is often the case that there remains a residuum in the problem which may be economically handled only by steam or gas auxiliaries.

*"The Value and Design of Water Power Plants as Influenced by Load Factor," *Journal* of the Franklin Institute, Oct., 1906.

Mr. Labelle.

But a short time ago the presence in any hydro-electric system of steam or gas auxiliaries was considered a confession of weakness in the hydraulic system. Fortunately, this false idea is fast losing ground, and it is recognized that the best of engineering is shown by their use, and in consequence fine hydro-electric opportunities are being utilized which were previously neglected."

Among Europeans, the clear-headed Swiss were the first to recognize the value of auxiliaries. After the plant at Chèvres, some four miles below Geneva, on the Rhône, had been for some time in operation, it became evident that the works would never be able to give a constant output single-handed, too many things causing the head on the turbines to fluctuate. The station had been built in the river near and parallel to the right shore; the barrage was composed of piers and balanced or Stoney gates of 10-m. spans, extending from the upper end of the power-house to the left shore. The forebay, in consequence, received all the detritus brought down by the river, not only from Geneva, but from the numerous towns located on Lake Leman and from the mountain streams emptying into it. In winter large bodies of frazil had to be handled, these occasionally completely stopping the works in spite of heating coils and the generous use of steam around the racks. Moreover, at certain seasons, the discharge of the river was considerably reduced. Briefly, the power output was very irregular, and as if these troubles were not sufficient, the river has begun to pile up sand and gravel in the upper end of the fore-bay.

The engineers of the plant, however, believe that they have found a remedy. They have constructed a combination trestle and racks extending from the upper end of the power-house, about 500 ft. up stream, to a point on the right bank, thereby enclosing the forebay. The structure is placed at such a small angle with the thread of the current that it is expected to divert the drift from the forebay and lead it over the wasteway provided in the barrage.

The Geneva Council, however, did not stop at the above device, but, having once recognized the utility of an auxiliary plant, it was not slow in erecting in the city what the writer considers a model electric power station throughout. The building is spacious and modern, and can accommodate machinery to generate more than 5 000 h.p. The generators are directly driven by Curtis turbines, and the steam is furnished by a battery of Babcock and Wilcox boilers, with all coal and ash conveyors, mechanical stokers, economizers, etc. It now seems that the problem of constancy of power in Geneva has been solved satisfactorily, and that the full normal output of the Chèvres station, with the help of its steam auxiliary, will be available at all times.

In the rapid advance of hydraulic-power transmission, both America and Europe have contributed largely, and each has taken

Mr. Labelle. advantage of the other's improvements in practice. It is true that Europe has the lead in turbine design and high voltage of generation, but America leads in high voltage of transmission and the development of auxiliaries. Besides, America is awakening to the importance of rational turbine designing, and at least one firm (the I. P. Morris Company, of Philadelphia) has cut loose from boiler-plate outfits, and has entered the field heretofore occupied exclusively by Swiss and German designers. It is to be hoped that other firms of turbine manufacturers in America will follow this example, and avail themselves of this surest way of increasing the efficiency of what is now the least efficient machine in all hydro-electric transformations.

Mr. Baum. F. G. BAUM, ASSOC. M. AM. SOC. C. E. (by letter).—The statement made by the authors, that a lap-welded pipe is stronger and more reliable than one built up of plates riveted together, is open to question. Out of an installation of four pipes of this kind, two failed at the weld, in one case after the pipe had been in service about seven years. The rupture showed the pipe to be blistered nearly the entire length at the weld, and, for a distance of about 9 in., there was a flaw running two-thirds through the metal. At the time of the break very cold water was being drawn through the pipe, and it is supposed that the contraction due to the cold (the pipe was flattened at the joint) caused an extra strain at the weld, and it yielded. Numerous joints of tested pipe of this kind have had to be discarded. A test of a few minutes is not sufficient.

The fact that pipes break occasionally makes it advisable to have as few cross-connections as possible, and these connections, where possible, should be normally closed. It is also advisable, where possible, to take a nozzle for two or more different units from the same pipe.

The vertical units cannot be justified on account of a saving of cost of power-house or ground space, as horizontal units could have been installed in the same space. The right-angled connections of the nozzles to the main pipes demanded by vertical units are open to objection on account of the loss of power, and the pipe connections are more costly and complicated than with horizontal units. There is also objection to the vertical unit on account of the fact that the water discharged from the buckets does not clear the wheel as well as in a horizontal unit; and certainly a horizontal bearing is preferable to a vertical bearing, other conditions being the same.

To obtain the same result with a horizontal unit would have required two discs and two sets of buckets as against one disc and one set of buckets for the vertical unit, assuming the buckets and nozzles to be of the same size. The extra cost, however, would be

offset by reduced losses in the nozzle connections and probably by increased wheel efficiency. Mr. Baum.

In laying out high-tension electrical connections, it should be borne in mind that a bare wire will give less trouble than one to which there are all kinds of connections, and flexibility should be sacrificed for simplicity. Series transformers, etc., should be eliminated, where possible, from the high-tension leads, and there should be no more switches than are absolutely necessary. As far as possible the switches, transformers, etc., should be within view by the operator, so that he may at once locate any trouble in the station, and not repeatedly throw the power on a piece of disabled apparatus which may be in a cell, out of view, not 20 ft. away. The plans show that the transformers, switches, etc., occupy more than one-half the building, which certainly is a very large proportion.

The use of steel towers on this line adds another experience to what will ultimately be the regular practice, for it takes no prophet to predict that some time in the future all high-tension, long-distance power lines will be on towers.

J. D. GALLOWAY, M. AM. SOC. C. E. (by letter).—Some of the authors' statements seem to be open to criticism, although the plant as a whole represents an example of high-class construction. Mr. Galloway.

Pipe Lines.—The pipe lines consist of about 2 400 ft. of 8-ft. riveted pipe, 2 300 ft. of 6-ft. riveted pipe and 2 460 ft. of 30-in., outer diameter, lap-welded pipe. The details of the construction of the large riveted pipe are lacking. It is generally a serious question as to how to preserve the shape of such pipe when built of relatively thin material. Bands of angle iron are sometimes used. The method of support is not stated, except that the pipe is on concrete piers. It would be interesting to know how close the piers are placed. The weight of water in the pipe is more than 3 000 lb. per lin. ft., which would seem to render the method of support quite a problem.

There is no mention of air-valves in this section of the pipe; the only means for air to enter is at the stand-pipes, below the receiver, they being connected to the 30-in. pipes. The distance from the reservoir to the receiver is about 4 500 ft., and, if there are no air-valves in that length, a break in the pipes would inevitably cause the collapse of the portion of the pipe above. Stiffening rings might prevent this, but it is doubtful. The collapse of pipe has occurred in a number of plants designed in a similar way, and the resulting damage was enormous.

The writer doubts very much the statement that a lap-welded 30-in. pipe is "stronger and more reliable than one built up of plates riveted together," and the following is offered as evidence:

At a plant which will be designated as "A" there are two 30-in.

Mr. Galloway. lap-welded pipes. Shortly after installation, one of these opened at the weld, causing much damage. After being in use seven years, another section opened at the weld. Inspection showed a very imperfect weld and also a shearing of the outer portion of the steel from the inner along the neutral axis. The steel seemed to be in layers. At plant "B" there are two lines of pipe, partly of 30-in., outer diameter, lap-welded. A number of sections (five, if memory serves correctly), were rejected in the field, owing to defective welds. Examination by drilling showed that in cases less than one-half the metal was in contact.

Another instance occurred at the Bishop plant of the Nevada Power, Mining and Milling Company, of the construction of which the writer had charge. A 24-in., outer diameter, riveted pipe, from the same factory that furnished the Necaxa pipes, was used, the maximum head being 1 068 ft. This pipe was subjected to a shop test similar to that of the Necaxa pipe, and was inspected by a prominent firm of inspectors. On arrival at the plant, one section was found to have opened along the weld a length of more than 5 ft. After being in place, with the water turned on for two weeks, another section opened at the weld, causing a shut-down and a troublesome patch.

At the Necaxa plant there are more than 2½ miles of weld, and engineers can appreciate the chance of such defects as mentioned. Personally, the writer believes such pipe to be entirely unsatisfactory for power plants. The resulting damage from a break would be enormous, both in cost of repairs and in prestige.

The use of riveted pipe is general throughout the West, and gives entire satisfaction. The writer calculates for a stress of 12 000 lb. per sq. in., and uses butt-strap joints, triple riveted. Joints of this type can be made with an efficiency of 80% and more. The riveting forms a positive connection, the strength of which has been established by numbers of tests. All parts can be inspected, and the chance of defects is reduced to a minimum. At Electra a riveted pipe supplying two 5 000-kw. generators, under 1 460 ft. head, designed as above, has been in use nearly two years, and no defect has shown.

A comparison of cost, made by C. D. Marx, M. Am. Soc. C. E., and the writer, was afforded by the design of pipes at Stanislaus, Cal. Bids were taken on the two pipes, 36 in. in diameter at the lower end, under 1 495 ft. head. Riveted and lap-welded joints were each taken as at 80% efficiency, the stress in the steel being 12 000 lb. per sq. in. Allowance was made in friction factors, due to less friction in the lap-welded pipe, the riveted pipe being of larger diameter. Including installation, the riveted pipe was 10% higher in cost than the lap-welded, while the time was about 40% longer

for the lap-welded pipe. The numerous failures of lap-welded pipe, mentioned above, together with the time required, led to the adoption of the riveted pipe at a higher cost. Mr. Galloway.

The design at Necaxa, which has one 30-in. pipe leading to each generator, seems to be not as economical nor as effective as one pipe serving two generators. A single 42-in. pipe has the same area as two 30-in. pipes, and, theoretically, the same quantity of metal in the shell. There is, however, a greater carrying capacity, due to decreased friction in the larger pipe. In laying, there is only one-half the number of pieces to be handled, and only one-half the number of longitudinal and transverse joints. In this, the cost is largely concerned with the number of parts handled, and not so much with their size.

At Necaxa the cost of the tunnel enters largely into the cost of these pipes. Judging from the photograph, Fig. 2, Plate CVI, there seems to be a space of about 2 ft. between the pipes, which is necessary to make the joints. Each is about 14 ft. wide. As three 42-in. pipes would occupy only 2 ft. more in width, one 16-ft. tunnel would have taken the place of two 14-ft. tunnels. As the tunnels are some 1 900 ft. long, and are excavated on an incline of 41°, and in a remote place, it would seem that a saving of at least $30 000 could have been effected by using larger pipes in this item alone. In the manufacture, there is but one joint instead of two, and the labor is reduced correspondingly. Heavier and larger pipes always come at a lower price per pound. Again, with two generators coupled to one pipe, the chances of a stoppage of flow of water and corresponding water hammer are much reduced. The writer regards the placing of two generators upon one pipe as the most effective insurance against damage to the pipe.

The Hydraulic Machinery.—In connection with the water-wheel, as designed with a vertical shaft, the authors state:

"This construction has many marked advantages for large units over impulse water-wheels heretofore built with horizontal shafts and single deflecting nozzles. The double nozzle reduces the size of both the jet and the bucket, and permits the use of a water-wheel of smaller diameter and higher speed of rotation without sacrifice of efficiency."

To one familiar with what has been done in California, this seems to be an absurd claim, in many respects, as no statement of the wheel efficiencies is given. In the design as made, the water entering the nozzles must make two right-angled bends, or 180°, before reaching the wheel. To compel water moving at from 15 to 20 ft. per sec., under some 1 400 ft. head, to turn an abrupt right angle would not seem as effective as to cause it to turn two angles of 30°, as in the Pelton Water-Wheel Company's designs. No de-

Mr. Galloway.

tail is given of the nozzles or the regulating device, so that comment cannot be made. To the writer, it does not seem possible to devise a simpler method of regulation than the deflecting nozzle, with the needle adjustment of the size of the jet. With a horizontal shaft, it is possible, and probably advisable, to place a wheel at each end, on generators of more than 3 000 kw. capacity. Little space has been saved, as the generators are some 24 ft. apart on centers. Single-wheel generators of 5 000 kw. capacity, on horizontal shafts, can be placed in 30 ft. Generally, the floor length depends upon the space required for transformers and switches and not on that required for the generators. The position of the nozzles, forming a couple, is theoretically correct, but no difficulty has been found in running generators of equal size under the same head, with a single nozzle. Little, if anything, is saved in head by the arrangement of placing the wheel near high water, as the part of the total head is a fraction of 1 per cent. The authors comment upon the higher speed possible by using the vertical shaft. The speed is 300 rev. per min. The writer knows of three 5 000-kw. generators, with single wheels on horizontal shafts, running constantly at 400 rev. per min., with a corresponding reduction in cost in the generators and wheel parts, both at the shop and in transportation. One of these, at de Sabla, was started nearly three years ago, and descriptions of it appeared in the technical press. Several more of the same size are now being installed. In fact, the speed of 400 rev. per min. for large generators seems to have become a standard. In the light of these facts, the claim for higher speed with the vertical shaft does not seem to be substantiated, as the examples cited were in operation before the Necaxa plant was built.

A point of interest, not noted by the authors, would be the action of the wheels under the variable head, due to the lowering of the storage reservoir. With the reservoir drawn down to a level 10 ft. over the lowest intake valve, there would be a decrease in head of about 8 per cent. The efficiency of pipe and water-wheels would suffer in this case, and information as to what the effect is would be interesting.

The writer is not familiar with the design of electrical apparatus, and makes no comment upon those parts.

The towers of the line are of excellent design throughout, and undoubtedly represent what will ultimately become a standard form of construction. Cheap poles and right-of-way questions have prohibited tower construction in the West.

Some points of the design claimed to be of much merit by the authors, and differing radically from construction with which the writer is familiar, have led to the foregoing comments, which, however, must not be taken as criticism. It is by the trial of new devices that progress is made.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

(INSTITUTED 1852.)

VOL. XXXIII. No. 2.

FEBRUARY, 1907.

Edited by the Secretary, under the direction of the Committee on Publications.

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NEW YORK 1907.

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Term expires January, 1909:
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The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

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CABLE ADDRESS: - - - "Ceas, New York."

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

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MINUTES OF MEETINGS.

OF THE SOCIETY.

FIFTY-FOURTH ANNUAL MEETING.*

January 16th, 1907.—The meeting was called to order at 10 A. M.; President F. P. Stearns in the chair; Chas. Warren Hunt, Secretary; and present, also, about 350 members.

The reading of the minutes of the meeting of January 2d, 1907, was dispensed with.

Messrs. W. C. Furber, J. C. Wagner and J. W. DuB. Gould were appointed tellers to canvass the Ballot for Officers for the ensuing year.

* A full report of the Fifty-Fourth Annual Meeting is printed on pages 54 to 108 of this number of *Proceedings*.

The Secretary announced:

The transfer of the following candidates by the Board of Direction, on January 3d, 1907:

FROM ASSOCIATE MEMBER TO MEMBER.

BENJAMIN THOMAS BUFFINTON, Fall River, Mass.
HARRISON PRESCOTT EDDY, Worcester, Mass.
HARRY HARTWELL, San Francisco, Cal.
WILLARD E. HERRING, Washington, D. C.
CURTIS HILL, St. Louis, Mo.
STEPHEN EPHRAIM KIEFFER, Monterey, Mexico.
THOMAS R. LAWSON, Troy, N. Y.

And that the following candidates were elected by the Board of Direction:

On January 3d, 1907:

AS JUNIORS.

LUDLOW OSMOND BARKER, JR., Bristol, Va.-Tenn.
LINDON BATES, JR., New York City.
ARTHUR MANCHESTER CRAIN, Detroit, Mich.
CHARLES MOSS DAVIS, Mitchell, Nebr.
ORVILLE LAMONT ELTINGE, Troy, N. Y.
RICHARDSON HAND, New York City.
OSCAR HASBROUCK, Albany, N. Y.
FRED WILLIS HASELWOOD, Altamont, Alameda Co., Cal.
EDWIN BENJAMIN KARNOPP, Empire, Canal Zone, Panama.
STEPHEN WOOD MCCLAVE, JR., Grantwood, N. J.
RICHARD MANSFIELD MERRIMAN, Central Valley, N. Y.
ALBERT LEO BRECHT MOSER, Chicago, Ill.
FRANCIS MARSHALL SMITH, San Francisco, Cal.
HARRY EDWIN SQUIRE, Mare Island, Cal.

The Annual Report of the Board of Direction, and the Annual Reports of the Secretary and of the Treasurer,* for the year ending December 31st, 1906, were presented, and, on motion, duly seconded, accepted and placed on file.

The Secretary made some announcements in reference to the programme of the Annual Meeting.

The Secretary reported the award by the Board of Direction of prizes for the year ending with the month of July, 1906, as follows:

The Norman Medal to John S. Sewell, M. Am. Soc. C. E., for

* For these reports, see pages 8 to 23 of the *Proceedings* for January, 1907 (Vol. XXXIII).

his paper entitled "The Economical Design of Reinforced Concrete Floor Systems for Fire-resisting Structures."

The Thomas Fitch Rowland Prize to George B. Francis and W. F. Dennis, Members, Am. Soc. C. E., for their paper entitled "The Scranton Tunnel of the Lackawanna and Wyoming Valley Railroad."

No award of the Collingwood Prize for Juniors was made.

The following were appointed members of the Nominating Committee:

JOSEPH STRACHAN....	*Representing*	*District No.*	*1.*	*To serve*	*2*	*years.*	
OTIS F. CLAPP.....	"	"	"	*2.*	"	"	"
ROBERT RIDGWAY ...	"	"	"	*3.*	"	"	"
CHARLES DAVIS	"	"	"	*4.*	"	"	"
IRA O. BAKER.....	"	"	"	*5.*	"	"	"
HUNTER MCDONALD .	"	"	"	*6.*	"	"	"
J. F. COLEMAN.....	"	"	"	*6.*	"	"	*1 year.*
J. B. LIPPINCOTT....	"	"	"	*7.*	"	"	*2 years.*

The Secretary presented a report* of the Board of Direction in the matter of a proposed Special Committee to report on Engineering Education.

The report was accepted and a letter-ballot ordered.

Richard L. Humphrey, M. Am. Soc. C. E., Secretary of the Special Committee on Uniform Tests of Cement, reported progress, and asked that the Committee be continued.†

The Committee was continued.

The Secretary presented a progress report‡ from the Special Committee on Rail Sections.

The report was accepted, and the Committee continued.

A progress report§ from the Special Committee on Concrete and Reinforced Concrete was presented by Richard L. Humphrey, M. Am. Soc. C. E., Secretary of that Committee.

The report was accepted and the Committee continued.

The Secretary presented the Report‖ of the Committee on Amendments to the Constitution.

John C. Trautwine, Jr., Assoc. M. Am. Soc. C. E., presented a Minority Report of the Committee on Amendments to the Constitution.

The Secretary read letters from Messrs. M. E. Yeatman, E. L. Corthell, George F. Swain, and S. Bent Russell, relating to the Amendments to the Constitution.

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* See page 63.
† See page 68.
‡ See page 69.
§ See page 69.
‖ See page 71.

Section 3, Article II, of the amendments proposed by the Committee, was amended by substituting the following:

"3.—Corporate Members shall be persons who are, or who have been, engaged in the profession or work of civil engineering in its broad sense, including its several branches."

The other proposed amendments were not amended.

The amendments, as amended by the Annual Meeting, were ordered sent to ballot.*

The report of the tellers† appointed to canvass the Ballots for Officers of the ensuing year was presented.

The President announced the election of the following officers:

President, to serve one year:

GEORGE H. BENZENBERG, Milwaukee, Wis.

Vice-Presidents, to serve two years:

JOHN A. BENSEL, New York City.
JOHN A. OCKERSON, St. Louis, Mo.

Treasurer, to serve one year:

JOSEPH M. KNAP, New York City.

Directors, to serve three years:

ALLAN HAZEN, New York City.
GEORGE W. TILLSON, Brooklyn, N. Y.
FRANK W. HODGDON, Boston, Mass,
JAMES CHRISTIE, Philadelphia, Pa.
HORACE E. HORTON, Chicago, Ill.
ARTHUR L. ADAMS, San Francisco, Cal.

Mr. Schneider and Mr. Collingwood conducted Mr. Benzenberg, the President-elect, to the chair.

Mr. Benzenberg addressed the meeting briefly.

Adjourned.

February 6th, 1907.—The meeting was called to order at 8.40 P. M.; V. H. Hewes, M. Am. Soc. C. E., in the chair; Chas. Warren Hunt, Secretary; and present, also, 86 members and 15 guests.

The minutes of the meetings of December 19th, 1906, and of January 2d, 1907, were approved as printed in the *Proceedings* for January, 1907.

* For amendments in full see *Proceedings*, Vol. XXXIII, page 81. (This number of *Proceedings*.)

† See page 105.

A paper by Spencer Cosby, M. Am. Soc. C. E., entitled "Lighthouse Construction in the Philippines," was presented by the Secretary, who also read a discussion thereon by C. E. L. B. Davis, M. Am. Soc. C. E.

The Secretary announced the receipt of a letter from F. R. Hutton, President of the American Society of Mechanical Engineers, inviting the members to be present at any of the monthly reunions of that society, which are held on the second Tuesday of each month.

The Secretary announced that the Thirty-ninth Annual Convention of the Society will be held in the City of Mexico, but that the date had not been fixed definitely.

Ballots for membership were canvassed, and the following candidates elected:

As Members.

Abel Morris Bienenfeld, San Francisco, Cal.
Frank Edward Bradley, New Rochelle, N. Y.
William Lee Church, Boston, Mass.
Franklin Clark Hand, Purcell, Ind. T.
James Judson Harding, Chicago, Ill.
Clarence Charles Lewis, Montevideo, Uruguay.
William Mulholland, Los Angeles, Cal.
Burt Hewitt Parsons, New York City.
James Harry Philips, Comstock, N. Y.
Frank Edson Shedd, Boston, Mass.

As Associate Members.

Robert Stuart Armstrong, Brooklyn, N. Y.
Joseph Manuel Babé, Havana, Cuba.
Laurence Adams Ball, Brooklyn, N. Y.
Guy Mannering Bassell, Erwin, Tenn.
Claude Berry, San Francisco, Cal.
Herbert Neal Cheney, Dorchester, Mass.
Thomas Remington Holden Daniels, San Francisco, Cal.
Walton Pruett Darwin, Washington, D. C.
Roy William Hebard, Empire, Canal Zone, Panama.
Shirley Clark Hulse, New York City.
Leigh Anson Hunt, Iola, Kans.
John Hunter, Youngstown, Ohio.
Harry Clifford Innes, Cincinnati, Ohio.
George Arthur Johnson, New York City.
Julius Gerardus Johnston, Austin, Tex.
Charles Sumner Lambie, Pittsburg, Pa.
Jacob Loewenstein, New York City.

ANDREW CAVITT LOVE, Port Allen, La.
ROBERT LOUIS GURDELSTON MEGGY, New York City.
SAMUEL JACOB OTT, Rutherford, N. J.
EMILE GEORGE PERROT, Philadelphia, Pa.
CHARLES WALTER PETERSEN, Chicago, Ill.
ROBERT LEMUEL SACKETT, Richmond. Ind.
PAUL DYER SIMPSON, Crawford, Nebr.
GEORGE ROSENGARTEN SINNICKSON, Haddonfield, N. J.
ISAAC JOSHUA STANDER, New York City.
THOMAS BRYAN WHITNEY, JR., New York City.
JAMES HUGH WISE, Berkeley, Cal.
DETHIC HEWITT WOOD, Chattanooga, Tenn.

As Associates.

EDWARD CARTWRIGHT CONSTANCE, St. Louis, Mo.
WILLIAM HILL COOPER, Amsterdam, N. Y.
CYRIL DE WYRALL, Ridgefield, N. J.
CHARLES CHURCH MORE, Seattle, Wash.

The Secretary announced:

The transfer of the following candidates by the Board of Direction, on February 5th, 1907:

From Associate Member to Member.

HARRY THOMAS CORY, Calexico, Cal.
GEORGE ALEC HARWOOD, New York City.
GEORGE STEVENS LEAVENWORTH, Troy, N. Y.
FRANK ELWIN WEYMOUTH, Glendive, Mont.

The election of the following candidates by the Board of Direction:

As Juniors.

On September 4th, 1906:

CHARLES WESLEY MALCOLM, Champaign, Ill.

On October 2d, 1906:

JEROME HENRY FERTIG, Montrose, Colo.

On December 4th, 1906:

MORRIS KETCHUM, New York City.

On January 3d, 1907:

GEORGE SAMUEL HILL, Chicago, Ill.
CHARLES TILESTON LEEDS, Ft. Bayard, N. Mex.

On February 5th, 1907:

Charles Wilbur Banks, Mt. Kisco, N. Y.
William Flint Bixby, Los Angeles, Cal.
Chester Robert Chadwick, New York City.
Harry Louis Coyne, New York City.
Frank Young Dorrance, Aspinwall, Pa.
Roberts Shepherd Foulds, Phœnixville, Pa.
George Hoag Gifford, Hollis, N. Y.
George Snyder Gildersleeve, Detroit, Mich.
Samuel Arnold Greeley, New York City.
Leroy Race Hinman, Boise, Idaho.
Eric Ture King, Arrochar, N. Y.
Louis Henry Lubarsky, New York City.
Edwin Lewis Lynch, Portland, Me.
Omer Evert Malsbury, Miraflores, Canal Zone, Panama.
Paul Ernest Oberndorf, Melville, La.
Warren Brown Thomson, Brewster, N. Y.
Albert Otis True, Pittsburg, Pa.
LeRoy Duncan Williams, Bevier, Mo.

The Secretary announced the following death:

Archibald Ronaldson Eldridge, elected Member October 2d, 1901; died January 17th, 1907.

Adjourned.

REPORT IN FULL OF THE FIFTY-FOURTH ANNUAL MEETING, JANUARY 16th and 17th, 1907.

Meeting Called to Order.

Wednesday, January 16th, 1907.—The meeting was called to order at 10 A. M.; President F. P. Stearns in the Chair; Charles Warren Hunt, Secretary; and present, also, about 350 members.

THE PRESIDENT.—The meeting will please come to order. The minutes of the meeting of January 2d, 1907, in accordance with the custom, will be printed in the January number of *Proceedings*, and come up in due course for action at the meeting of February 6th, 1907; in view of which the reading of these minutes will be dispensed with, unless a call is made for them. The chair hears no objection, and this course will be followed.

Tellers Appointed.

I will appoint as tellers to canvass the Ballots for Officers Messrs. W. C. Furber, J. C. Wagner, and J. W. Du B. Gould. The ballot will not close until 12 o'clock, and ballots will be received up to that time; but, following the custom, I will ask the tellers to proceed at once with the counting. They will find assistance in the library from the employees of the Society.

The Secretary will make some announcements.

Announcements.

THE SECRETARY.—Mr. President, all members have had the printed programme of the meeting, and there is little to be added. There is no change in any of the events on that programme, but the programme states that the Committee will arrange this afternoon several short trips to several nearby points of engineering interest, so that members may choose whichever of them is of special interest.

The excursions which have been arranged for this afternoon, the start for which will take place immediately after luncheon, are as follows:

To the new Lackawanna Terminal in Hoboken. Mr. Lincoln Bush, Chief Engineer, and Mr. W. G. Triest, of Snare & Triest, the contractors, will be here, and both these gentlemen will go with those who care to take that particular trip.

Mr. O. F. Nichols, Consulting Engineer of the Department of Bridges, and Mr. J. A. Knighton, Engineer in charge of construction of the Blackwell's Island Bridge, will pilot a party to that bridge, in case it is made up.

Mr. George H. Pegram, Chief Engineer of the Interborough Rapid Transit Company, has invited all members to visit the Fifty-ninth Street Power Station, either this afternoon or at any time during this week. They will be admitted at any time by showing their badges, and if sufficient interest is manifested to make up a party for this afternoon, such a party will make the visit under Mr. Pegram's guidance.

Another excursion arranged for is to the Pennsylvania Railroad Tunnel; the site of the new Pennsylvania Terminal at Eighth Avenue and Thirty-second Street; the Power Plant for driving tunnels under the East River, which is located at First Avenue; and that part of the tunnel crossing Manhattan Island. Mr. G. C. Clarke, Resident Engineer of the terminal, and J. H. Brace, Resident Engineer of the other part of the line, and Mr. D. L. Hough, who has the contract for that part of the work, will all be here to pilot that party.

I rather expect that there will be more people present later, and possibly these announcements will be repeated, and at that time these gentlemen will probably be here, and I will ask them to say a word or two to you about the work to be seen, so as to give the proper points of view to members, in order that they may be able to decide to which they wish to go, and also that they may subsequently recognize their guides.

These are all the announcements regarding the programme, Mr. President.

I have to announce, for the sake of the record, the transfer of candidates from the grade of Associate Member to that of Member, and the election of candidates as Juniors, by the Board of Direction, on January 3d, 1907.*

THE PRESIDENT.—The Secretary will now present the Annual Report of the Board of Direction.

Report of the Board of Direction.

The Secretary read the Report of the Board of Direction.†

THE PRESIDENT.—Will you continue with the report of the Secretary?

THE SECRETARY.—If there are any members present who have not a copy of this report, there are plenty of them here, and I would be glad to have them distributed.

Report of the Secretary.

The Secretary read his report.‡

THE PRESIDENT.—What is your pleasure in regard to these reports—the reports of the Board of Direction and of the Secretary?

It was duly moved and seconded that they be accepted and placed on file.

THE PRESIDENT.—It is moved and seconded that these reports be accepted and placed on file. Those in favor say "aye"; opposed, "no". The motion is carried unanimously.

We will hear next the report of the Treasurer, Mr. Knap.

Report of the Treasurer.

The Treasurer read his report.§

JOSEPH M. KNAP, TREASURER, AM. SOC. C. E.—I should like

* See Minutes of Meetings, p. 48.
† See *Proceedings*, Vol. XXXIII, p. 8 (January, 1907).
‡ See *Proceedings*, Vol. XXXIII, p. 16 (January, 1907).
§ See *Proceedings*, Vol. XXXIII, p. 19 (January, 1907).

to add a word in a general way to this report, which perhaps may be of interest. Our mortgage debt in January, 1904, was $55 000. It is now $175 000. That is a increase of our mortgage indebtedness of $120 000, but during that time the extraordinary expenses for lot and buildings, and so forth, were about $162 000, and for the expenses of the International Engineering Congress about $35 000, making a total of what we might call extraordinary expenses of $197 000, but showing an increase in the mortgage of only $120 000.

I may say, in conclusion, that the financial condition of the Society is most excellent, holding out the prospect of the speedy reduction of this bonded indebtedness from year to year.

THE PRESIDENT.—You have heard the report of the Treasurer. What action shall be taken upon it?

On motion, duly seconded, the report was accepted and placed on file.

THE PRESIDENT.—Next in the order of business is the announcement of the awards of prizes by the Board of Direction.

The Secretary read the following announcement:

Award of Prizes.

In accordance with the recommendations of the Committee appointed for the purpose, the Board of Direction has made the following awards for the year ending with the *Transactions* of July, 1906:

The Norman Medal to John Stephen Sewell, M. Am. Soc. C. E., for his paper entitled "The Economic Design of Reinforced Concrete Floor Systems for Fire-resisting Structures."

The Thomas Fitch Rowland Prize to George B. Francis, and William F. Dennis, Members, Am. Soc. C. E., for their paper entitled "The Scranton Tunnel of the Lackawanna and Wyoming Valley Railroad."

No award of the Collingwood Prize for Juniors has been made by the Board.

Nominating Committee.

THE PRESIDENT.—The report of the Secretary upon the suggestions from the various districts in the matter of the Nominating Committee.

THE SECRETARY.—In accordance with the usual custom, Mr. President, the suggestions received from the membership in the matter of appointments of members of the Nominating Committee from the various districts have been tabulated, and by districts are as follows, and, if I might suggest, Mr. President, I think it would be well when one district is read to attend to the appointment from it before proceeding with the next.

District No. 1.—Total number of votes received, 125; distributed as follows:

Joseph Strachan	48
W. E. Belknap	24
G. C. Clarke	6
Henry W. Hodge	2
George B. Francis	2
Alfred Noble*	2
R. H. Tingley	2
W. J. Wilgus	2

The following have received one vote each:

Frederick Auryansen,	R. C. Hollyday,
A. L. Bowman,*	Joseph M. Knap,*
Josiah A. Briggs,	Horace Loomis,
C. W. Buchholz,	Charles Macdonald,
Albert Carr,	O. F. Nichols,
Theodore Cooper,	Edward P. North,
A. B. Corthell,	Stacy B. Opdyke, Jr.,
Elmer L. Corthell,	A. McC. Parker,
W. H. Coverdale,	Walter H. Sears,
Alfred Craven,	Charles H. Snow,
Foster Crowell,	George D. Snyder,
William G. Ford,	S. C. Thompson,
W. B. Fuller,	John Thomson,
George Gibbs,*	George W. Tillson,*
Charles H. Graham,	Louis L. Tribus,
George T. Hammond,	Charles E. Trout,
William J. Haskins,	Clement I. Walker,
William R. Hill,	F. S. Williamson,
Joseph B. Wright.	

The President.—You have heard the report from District No. 1. What is your pleasure?

G. W. Tillson, M. Am. Soc. C. E.—As Mr. Strachan has received exactly double the number of votes of the man next below him, I move that he be elected to the Nominating Committee from District No. 1.

Motion seconded.

The President.—It is moved and seconded that Mr. Strachan be elected as a member of the Nominating Committee from District No. 1. Those in favor of that motion will say "aye"; those opposed, "no." The motion is carried.

The Secretary.—From District No. 2 the nominations are:

* Ineligible.

Nominating Committee (continued).

District No. 2.—Total number of votes received, 48; distributed as follows:

Otis F. Clapp	10
Joseph R. Worcester	6
Leonard Metcalf*	3
Fred. Brooks	3
William H. Moore	2
S. E. Tinkham	2

The following have received one vote each:

C. Frank Allen,	L. J. Johnson,
Charles M. Allen,	George A. Kimball,
William M. Bailey,	Henry Manley,
H. Bissell,*	George N. Merrill,
Dexter Brackett,	Hiram A. Miller,
George C. Carpenter,	Arthur T. Safford,
J. Vinton Dart,	Albert F. Sickman,
Arthur Willard French	F. P. Stearns,*
Frank L. Fuller,	George F. Swain,
A. B. Hill,	Leonard C. Wason,
Frank W. Hodgdon,*	William Wheeler.

C. Frank Allen, M. Am. Soc. C. E.—Mr. President, I move that Mr. Otis F. Clapp be elected member of the Nominating Committee for District No. 2.

Motion seconded.

The President.—It is moved and seconded that Mr. Otis F. Clapp be elected as a member of the Nominating Committee for District No. 2. Those in favor of the motion will say "aye;" those opposed, "no." The motion is carried.

The Secretary.—From District No. 3 the following nominations have been received:

District No. 3.—Total number of votes received, 67; distributed as follows:

Robert Ridgway	15
George F. Stickney	9
Gardner S. Williams	5
William A. Brackenridge	3
Clarence Coleman	3
William de la Barre	2
Benjamin Douglas	2
E. A. Fisher*	2
Charles M. Morse	2
Palmer C. Ricketts	2

The following have received one vote each:

* Ineligible.

C. Loomis Allen,	Louis M. Knapp,
Henry C. Allen,	Emil Kuichling,*
Le Grand Brown,	Clarence R. Neher,
M. J. Butler,	Willard Pope,
William B. Cogswell,	L. W. Rundlett,
C. E. L. B. Davis,	Cecil B. Smith,
James H. Edwards,	Charles F. Stowell,
E. E. Haskell,	George F. Stickney,
Franklin A. Hinds,	A. H. Sutermeister,*
Francis E. House,	F. E. Turneaure,
Thomas C. Keefer,	C. A. P. Turner,

The President.—You have heard the report on District No. 3; what is your pleasure?

E. B. Codwise, M. Am. Soc. C. E.—I move that Mr. Ridgway be declared elected as member of the Nominating Committee from District No. 3.

The President.—It is moved and seconded that Robert Ridgway be elected a member of the Nominating Committee from District No. 3. Those in favor of the motion will say "aye;" those opposed, "no." The motion is carried.

The Secretary.—The following nominations have been received from District No. 4:

District No. 4.—Total number of votes received, 72; distributed as follows:

Charles Davis	32
Joseph Ripley	4
Benjamin T. Fendall	2
Thomas H. Johnson	2

The following have received one vote each:

Kenneth Allen,	Morris Knowles,
J. A. Atwood,	Theodore A. Leisen,
Frank L. Averill,	D. E. McComb,
D. S. Carll,	Edgar Marburg,*
Mendes Cohen,	Mansfield Merriman,
Robert A. Cummings,	S. P. Mitchell,
A. P. Davis,	Frederick H. Newell,
George S. Davison,	Alexander Orr,
John Sterling Deans,	H. T. Porter,
William Copeland Furber,	Alfred M. Quick,
Herbert T. Grantham,	Joseph T. Richards,
James H. Harlow,	E. M. Scofield,
V. K. Hendricks,	Emil Swensson,*
C. W. Hudson,	John C. Trautwine,*
Richard L. Humphrey,	George Smedley Webster,
Richard Khuen,	W. G. Wilkins.

* Ineligible.

Nominating Committee (continued).

J. N. CHESTER, M. AM. SOC. C. E.—I move that Charles Davis be elected a member of the Nominating Committee from District No. 4.

Motion seconded.

THE PRESIDENT.—It is moved and seconded that Mr. Charles Davis be elected as a member of the Nominating Committee from District No. 4. Those in favor of the motion will say "aye;" opposed, "no." The motion is carried.

THE SECRETARY.—I would like to ask again, for the sake of the stenographer and the records, that each member give his name. It is rather difficult to keep track of this unless he does.

The nominations from the Fifth District are:

District No. 5.—Total number of votes received, 67; distributed as follows:

IRA O. BAKER	34
JOHN W. ALVORD*	3
ALBERT F. REICHMANN	2
SAMUEL ROCKWELL	2
W. G. BRENNEKE	2

The following have received one vote each:

DANIEL BONTECOU,	CHARLES F. LOWETH,
C. S. BURNS,	DANIEL W. MEAD,
T. L. CONDRON,	HIRAM PHILLIPS,
E. B. FAY,	WILLIAM V. POLLEYS,
EDWARD FLAD,	C. D. PURDON,
CHARLES FRANCIS,	WILLIAM G. RAYMOND,
CHRISTOPHER L. GATES,	A. F. ROBINSON,
L. F. GOODALE,	S. BENT RUSSELL,
BERNARD L. GREEN,	E. C. SHANKLAND,
E. A. HANDY,	WILLIAM B. STOREY, JR.,*
HORACE E. HORTON,*	HARRY E. TALBOTT,
CHARLES A. JUDSON,	J. A. L. WADDELL.

THE PRESIDENT.—You have heard the report from District No. 5. What is your pleasure?

M. R. SHERRERD, M. AM. SOC. C. E.—I move that Ira O. Baker be elected member of the Nominating Committee from District No. 5.

Motion seconded.

THE PRESIDENT.—It is moved and seconded that Mr. Ira O. Baker be elected as a member of the Nominating Committee from District No. 5. Those in favor of the motion will say "aye;" those opposed, "no." The motion is carried.

THE SECRETARY.—The nominations from District No. 6 are:

* Ineligible.

District No. 6.—Total number of votes received, 55; distributed as follows:

HUNTER MCDONALD	9
J. F. COLEMAN	7
HENRY B. RICHARDSON	4
W. B. W. HOWE	3
ARTHUR HIDER	2
RICHARD MONTFORT	2

The following have received one vote each:

T. H. ALDRICH,	B. M. HARROD,
D. M. ANDREWS,	JOHN B. HAWLEY,
E. E. BETTS,	JULIAN W. KENDRICK,
M. J. CAPLES,	W. A. LELAND,
C. L. CARPENTER,	GEORGE K. LITTLE,
CHARLES S. CHURCHILL,	C. A. LOCKE,
W. W. COE,	D. W. LUM,*
GEORGE G. EARL,	M. MORRIS,
C. F. W. FELT,	ARTHUR PEW,
H. FERNSTROM,	A. M. SCOTT,
ROBERTO GAYOL,	H. K. SELTZER,
EDWARD GRAY, JR.	THOMAS U. TAYLOR,
J. P. HALLIHAN,	R. A. THOMPSON,

J. S. WALKER.

Nine of the members in this District have voted for two candidates; the names of all the candidates voted for have been recorded.

THE PRESIDENT.—You have heard the report from District No. 6. What is your pleasure?

R. MONTFORT, M. AM. SOC. C. E.—I move that Hunter McDonald be elected member of the Nominating Committee from District No. 6.

THE PRESIDENT.—Is the motion seconded?

Motion seconded.

THE PRESIDENT.—It is moved and seconded that Mr. Hunter McDonald be elected as a member of the Nominating Committee from District No. 6. Those in favor of the motion will say "aye;" opposed, "no." The motion is carried.

THE SECRETARY.—District No. 7 sends the following nominations:

District No. 7.—Total number of votes received, 65; distributed as follows:

E. DURYEA, JR.	4
J. B. LIPPINCOTT	4
W. W. HARTS	4

* Ineligible (resides in Washington).

Nominating Committee (continued)

W. H. Sanders	4
Virgil G. Bogue	3
D. C. Henny	3
Franklin Riffle	3
A. L. Adams*	2
John D. Galloway	2
Clarence T. Johnston	2
C. A. Morse	2
Theron A. Noble	2
J. H. Quinton	2
H. N. Savage	2

The following have received one vote each:

G. M. Bacon,	Thomas W. Jaycox,
Frank E. Baxter,	C. D. Marx,
James W. Beardsley,	F. O. Marvin,*
H. J. Burt,	S. D. Mason,
Eugene Carroll,	P. N. Nunn,
George L. Dillman,	George T. Prince,
Charles E. Fowler,	F. Rosenberg,
Edward Gillette,	Andrew Rosewater,
Hubert E. Green,	D. W. Ross,
Homer Hamlin,	James D. Schuyler,
Arthur Hider,	H. A. Sumner,
Louis C. Hill,	J. H. Wallace,
F. W. D. Holbrook,	A. J. Wiley.

The President.—Will you please read again the four who have four votes each, who are eligible?

The Secretary.—E. Duryea, Jr., J. B. Lippincott, W. W. Harts and W. H. Sanders.

The President.—You have heard the report, gentlemen; what is your pleasure?

Clemens Herschel, M. Am. Soc. C. E.—I move that the Nominating Committee be represented by Mr. J. B. Lippincott from District No. 7.

Motion duly seconded.

The President.—Gentlemen, you have heard the motion that Mr. J. B. Lippincott be elected as a member of the Nominating Committee for the Seventh District. Those in favor will please say "aye;" opposed, "no." The motion is carried.

The Secretary.—Mr. President, I omitted to make a statement in regard to District No. 6. A. H. Zeller, Assoc. M. Am. Soc. C. E., was elected on January 17th, 1906, to represent District No. 6 on

* Ineligible.

the Nominating Committee. Since that time the Society has been redistricted, and St. Louis, from which city Mr. Zeller was elected, is now in District No. 5. Mr. Zeller was elected for two years. He died on November 2d, 1906. There must, therefore, be two members of the Nominating Committee appointed at this meeting from District No. 6, one to serve two years and one to serve one year, as it has no representative now except the gentleman who has just been appointed, Mr. Hunter McDonald; and I should like to say that in making this report a number of ballots were received from members who voted two names, and all the names voted have been put on this list and given one vote each, whether the member voted for one man or voted for two men. I could not see any other way to report the vote.

MR. KNAP.—Who is the second on the list, next to the man elected?

THE SECRETARY.—J. F. Coleman; Hunter McDonald has been elected.

MR. KNAP.—I move that Mr. Coleman be elected to serve one year.

THE PRESIDENT.—We will take up first the election of Mr. Coleman as a member of the Nominating Committee, and then we will decide which one shall serve for two years.

Motion seconded.

THE PRESIDENT.—It is moved and seconded that Mr. Coleman be elected as a member of the Nominating Committee from District No. 6. Those in favor of the motion will say "aye;" those opposed, "no." The motion is carried.

Now, a motion will be in order to see which one shall serve for two years.

EMIL SWENSSON, M. AM. SOC. C. E.—I move that Mr. Hunter McDonald, inasmuch as he was named first, be designated as the member to serve two years.

Motion seconded, stated and carried.

THE PRESIDENT.—The next is the report of the Board of Direction in the matter of the Special Committee on Engineering Education.

The Secretary presented the following report:

TO THE AMERICAN SOCIETY OF CIVIL ENGINEERS:

Report on Proposed Committee on Engineering Education.

At the Business Meeting of the Annual Convention, June 27th, 1906, the following resolution was adopted:

"*Resolved,* That it is the sense of this meeting that a Special Committee be appointed to report on the status of Engineering Education in this country, and to recommend measures calculated to place it on the highest plane of efficiency."

Report on Proposed Committee on Engineering Education (continued).

This resolution was then "referred to the Board of Direction, for consideration," under Article VI, Section 12, of the Constitution.

In compliance with the provisions of Article VI, Section 12, of the Constitution, the Board of Direction has considered the resolution, and gives below arguments for and against the appointment of such Special Committeee.

Arguments in Favor.

The views of technical educators differ widely as to some of the fundamentals of preparatory educational work, and therefore there are as many varieties of Civil Engineering graduates as there are Technical Schools. The report of such Committee would tend toward more uniformity in preparation for professional work. Among engineers who have been in active practice for years, and have had opportunities for close observation of recent graduates, there is a more or less strong belief that changes might be made in existing courses of instruction, which would not only increase the immediate efficiency of such graduates, but would also prepare them better for the more advanced responsibilities which will come to them later.

It is believed that the work of such Committee would be of great benefit to the future of the engineering profession, and that therefore its appointment would be well within the scope of the objects of the Society as set forth in Article I, Section 3 of the Constitution.

Arguments Against.

It is questionable whether this is a proper subject for a report by a Special Committee in the sense intended in the Constitution of the Society, which provides that such Special Committees may be appointed "to report upon engineering subjects."

This Society is not an educational institution, and its function is to deal only with the engineer and not with the student.

If such a Committee were made up largely of educators its report would probably not change to any great extent existing practice in technical schools, and it is doubtful if men of any other class are qualified for membership on such a Committee.

The Board of Direction recommends to the Society that a Special Committee be appointed to report on the status of Engineering Education in this country, and to recommend measures calculated to place it on the highest plane of efficiency.

By order of the Board of Direction,

Chas. Warren Hunt,
Secretary.

THE PRESIDENT.—You have heard the report of the Board of Direction. The Constitution provides that in a case like this a motion may be made for the issue of a letter-ballot, and if the motion is approved by an affirmative vote of two-thirds of the members present at this meeting the ballot shall be sent out to the members of the Society. What is your pleasure?

Discussion on Proposed Committee on Engineering Education.

JOHN F. O'ROURKE, M. AM. SOC. C. E.—I move that the report be accepted and laid on the table.

Motion seconded.

THE PRESIDENT.—It is moved and seconded that the report be accepted and laid on the table.

MR. CHESTER.—I think it is worthy of consideration. I should like to see a motion to have that report adopted, and I think it is taking too hasty an action to table such an important motion.

THE PRESIDENT.—The motion before the meeting is to lay on the table. It cannot be amended. It can be voted down. A vote will be taken on Mr. O'Rourke's motion to accept the report and lay it on the table.

MR. KNAP.—I would like to ask Mr. O'Rourke to explain it.

MR. O'ROURKE.—I will withdraw my motion to lay on the table, and will make that motion after the motion to receive has been voted upon.

THE PRESIDENT.—The motion is to accept or receive the report.

Motion seconded.

THE PRESIDENT.—Is there any discussion? If not, the chair will put the motion.

OSCAR LOWINSON, ASSOC. M. AM. SOC. C. E.—I would like to ask whether the acceptance of that motion without a subsequent motion is all that is necessary for the issuance of this ballot.

THE PRESIDENT.—It is not.

MR. LOWINSON.—Then, Mr. President, I move to amend that motion by adding that the Society authorizes the Board of Direction to issue a letter-ballot for that purpose.

Motion seconded.

THE PRESIDENT.—It is moved and seconded that the motion to accept the report be amended by a motion that the Board of Direction be directed to issue a letter-ballot. The question is on the amendment. Is there any discussion on the amendment?

MR. LOWINSON.—Possibly it might be necessary to say one word, only. I think the subject is of sufficient importance to warrant that it be discussed thoroughly by the Society, and, without going into any details in connection with the advisability of it, I think it is advisable that the membership should decide the subject and not shelve it, and that was my reason for making the motion in that shape.

Discussion on Proposed Committee on Engineering Education (continued).

MR. O'ROURKE.—My motion in regard to the tabling of this report was not so much due to a disagreement with the report as to the fact that we ought to set apart a week or two to discuss it. We only have a very short time to-day to do the work of the Annual Business Meeting; and, to bring in this question of going into the regulation of engineering education would take all the time that ought to be devoted to the business meeting, that the members may laud the particular institutions where they were educated to show how these institutions send out great engineers, and a number of the important things that went on in order to do that. I think that engineering education will go on with the process of education as it now goes on, and will go on as long as we live. If we are able to take advantage of the opportunities for education we become better educated, but as soon as the Society goes into the discussion of that it puts everything else away that we might want to do while we discuss this everlasting question, because it would be everlasting.

When we get into this subject we would get everybody who had graduated from an engineering institution showing how his particular institution had turned out a great engineer, and giving the reasons for not going back on the system which has turned out so many promising students and engineers. On that account, Mr. President, with full regard to the report of the Board of Direction and a desire to pay them every courtesy, my motion was that their report be received and placed on file. That has nothing to do with the adoption of the report, and I wanted to make a motion to lay the matter on the table afterward, but now, having declared what I believe to be the best thing to do with that report, anybody else has my permission to make that motion.

MR. KNAP.—The last speaker has taken up a lot of time already—I might even say an undue amount. I would say, sir, that it is not necessary for me to discuss this at very great length, but, at least, we might take a vote on it and put it out to the Society by letter-ballot. It seems to me that a few moments, or half an hour, would not be wasted on this important subject, and I hope we will have a further opportunity to discuss it.

THE SECRETARY.—May I call attention to the wording of the Constitution? The Constitution says "if a motion for the issue of a letter-ballot thereon receive the affirmative vote of two-thirds of the Corporate Members present, the Board of Direction shall" do something. It appears to indicate that a motion to do something must be made.

MR. ALLEN.—In relation to a matter of fact stated by Mr. O'Rourke, I believe there is an opportunity for correction. I have been for more than twelve years a member of The Society for the Promotion of Engineering Education, and I think perhaps you

could get some idea of what the drift of the discussion might be from their proceedings; and from their proceedings it has not been true that at any meeting that I have ever attended which they have ever held that the occasion has been taken advantage of to exploit the advantages each of his own system of education. I do not believe that the discussion would take that form at all. I think we can judge by experience, rather than by an off-hand guess.

A MEMBER.—Question.

THE PRESIDENT.—The question is on the amendment. If there is no further discussion, it will be put to a vote, as it requires a two-thirds vote of the Corporate Membership present, because it virtually requires the Board of Direction to issue a ballot. I will ask those in favor of the motion to stand until they are counted.

A MEMBER.—May I hear what the question is?

THE PRESIDENT.—The question is, shall the issue of a letter-ballot to the members be directed?

THE SECRETARY.—(After making a count.) 105.

THE PRESIDENT.—Those opposed will stand up.

MR. O'ROURKE.—I rise to a point of order, Mr. President. My point of order is that the Constitution requires that two-thirds of the members present shall vote in the affirmative. I hold that no negative vote is necessary in this connection, but that the proportion of the affirmative votes be ascertained to be at least two-thirds.

THE PRESIDENT.—The point of order is well taken.

A MEMBER.—I would rise to another point of order. I do not think the absence of a vote is necessarily a negative vote. There may be people here who do not wish to vote against it.

THE PRESIDENT.—There may be people present, also, who are not members.

MR. O'ROURKE.—I think everybody registered is supposed to be present at this meeting, everybody who has registered to-day.

THE PRESIDENT.—There is a way in which it can be ascertained how many members are present—of ascertaining those who are here present and not voting.

THE SECRETARY.—Everybody present who is not a Corporate Member of the Society stand up and be counted.

There are 20 to be deducted. Now I will count the whole membership.

MR. CHESTER.—I think the new construction put upon this might possibly influence this vote, had it been known prior to the votes being taken; and I make the motion that the vote be taken again and be counted, with the knowledge that it is going to be counted in this way.

THE PRESIDENT.—I think the point is well taken, because many members may have remained in their seats with the expectation

Discussion on Proposed Committee on Engineering Education (continued).

that their votes would not be counted either for or against the motion. I will, therefore, ask for another vote on the affirmative. Those in favor of the motion will please stand until they are counted.

THE SECRETARY.—(After making a count.) 131.

THE PRESIDENT.—131 have voted in the affirmative. The Secretary will now count the whole number of members present, deducting 20 for the non-corporate members.

THE SECRETARY.—(After making a count) 208 less 20; 188, Mr. President.

THE PRESIDENT.—The total number of members present is 188; necessary for a choice, 126. The vote in the affirmative is 131, and the amendment is carried. This is a peculiar motion, and it now recurs on the original motion.

MR. O'ROURKE.—This American Society of Civil Engineers is ruled by a Constitution and by-laws and parliamentary rules. There was a vote taken here; number, 105. There was no motion to reconsider, and as a motion to reconsider is necessary before a second vote can be taken, I hold that the motion in favor of this thing is 105, and that the second vote is informal, and that the motion is defeated.

THE PRESIDENT.—The chair will rule against this view, on the ground that the result of the vote had not been announced, that the vote was taken under a misapprehension, and that this Society is not so closely tied down to parliamentary rules that it must reach a decision contrary to the wishes of the members present.

MR. O'ROURKE.—Then, Mr. President, I suggest that this committee, if appointed, shall take instructions in an engineering sense, on the necessity of conducting proceedings regularly.

MR. KNAP.—I would add to that that there be not too much instruction on the part of the member.

THE PRESIDENT.—I think that the motion that has been made directs the Board of Direction to issue the letter-ballot, and it seems to me to be rather unnecessary to take the time required for a further vote as to the acceptance of the report, unless somebody requests such action.

Report of Committee on Uniform Tests of Cement.

I will ask if there is any report of the Special Committee on Uniform Tests of Cement. Mr. George S. Webster is chairman of that committee.

RICHARD L. HUMPHREY, M. AM. SOC. C. E.—The Special Committee on Uniform Tests of Cement has under consideration the making of tests for determining the proper methods of making cement, the proper percentage of sand, the proper percentage of water required in certain methods, and those tests are in such a shape that it does not warrant a report at this time. The Committee has made some minor changes in its report, particularly

in the phrasing of certain sentences, which it is not necessary to read as it will be transmitted in the formal report, and the Committee asks to be continued.

EDWARD P. NORTH, M. AM. SOC. C. E.—I move that the Committee be continued.

Motion seconded, stated and carried.

THE PRESIDENT.—The next is the report of the Special Committee on Rail Sections.

Report of Committee on Rail Sections.

THE SECRETARY.—The Committee on Rail Sections has handed me the following report and asked me to read it at this meeting.

Your Special Committee on Rail Sections respectfully reports as follows:

At the Annual Convention, held at Thousand Islands in June, 1906, the following resolution was passed:

"Resolved, That the Report of the Special Committee on Rail Sections be referred back to the Committee for further action and final report, in the hope that the majority and minority may harmonize their views and present a unanimous report."

It has not been thought practicable or desirable to attempt to make a unanimous and final report at this time, and your Committee, therefore, reports progress and asks to be continued for further consideration of the subject and further report.

H. G. PROUT, *Chairman, pro tem.*
WM. R. WEBSTER, *Secretary, pro tem.*

THE PRESIDENT.—You have heard the report of the Committee on Rail Sections. What is your pleasure?

MR. SWENSSON.—I move, Mr. President, that it be accepted and the Committee continued.

Motion seconded.

THE PRESIDENT.—It is moved and seconded that the report be accepted and the committee continued. Those in favor of that motion will say "aye;" opposed, "no." The motion is carried.

Report of Committee on Concrete and Reinforced Concrete.

The next is a report of the Special Committee on Concrete and Reinforced Concrete.

C. C. SCHNEIDER, PAST-PRESIDENT, AM. SOC. C. E.—This report is in the hands of the Secretary of the Committee, who will read it to the Society.

Mr. Humphrey presented the following report:

President and Members of the
AMERICAN SOCIETY OF CIVIL ENGINEERS,

GENTLEMEN:—Your Special Committee on Concrete and Reinforced Concrete desires to present the following report on the work accomplished during the past year:

In the matter of the collation of existing literature and the results of previous investigations, your Committee finds the amount

Report of Committee on Concrete and Reinforced Concrete (continued).

of work entailed much greater than had been anticipated, and the close of the year finds the reports of the various sub-committees on this subject only partially completed; inasmuch as this work requires searches in libraries involving a great amount of time, it is the opinion of your Committee that it is unreasonable to expect it to do this work unaided. It has therefore appealed to the Secretary of the Society and he has agreed to make such searches in the library of the Society as may be deemed necessary by the Committee. There is every reason to believe that this work will be completed in the fore part of the present year. During the year your Committee has planned, and there is being executed under its direction, an extensive series of tests of concrete and reinforced concrete, with the object of obtaining sufficient data to serve as the basis in the preparation of a report.

This work is being done in the Structural Material Testing Laboratories of the United States Geological Survey at St. Louis, Mo., and in the laboratories of some of the technological institutions possessing the requisite facilities.

The investigations at St. Louis are made possible by an appropriation of $100 000 made by the last Congress and available until June 30th, 1907; the present Congress is expected to appropriate a like sum of money, thus extending the work until June 30th, 1908.

Your Committee desires to express its thorough appreciation and thanks for the interest taken and the untiring assistance rendered on behalf of this appropriation by a fellow member of our Society, the Hon. William H. Wiley, Member of Congress from New Jersey.

Two bulletins will be issued shortly by the United States Geological Survey, giving the results of the tests thus far made at St. Louis and in the laboratories of the various technological institutions, and it is the intention, if practicable, for the Geological Survey to issue monthly or bi-monthly bulletins, giving the results of tests as rapidly as available.

From now on, your Committee believes that the great amount of necessary work of a preliminary character which has been done will begin to bear fruit and show the magnitude of the problem entrusted to the Committee.

Your Committee asks for its continuance.

Respectfully submitted on behalf of the Committee,

C. C. SCHNEIDER, *Chairman.*
RICHARD L. HUMPHREY, *Secretary.*

Committee:

C. C. SCHNEIDER,
EMIL SWENSSON,
RICHARD L. HUMPHREY,
JOHN E. GREINER,
W. K. HATT,
OLAF HOFF,
ROBERT W. LESLEY,
J. W. SCHAUB,
A. N. TALBOT,
J. R. WORCESTER.

THE PRESIDENT.—You have heard the report of the Special Committee on Concrete and Reinforced Concrete. What is your pleasure?

MR. LOWINSON.—I move that the report be accepted and the Committee continued.

Motion seconded, stated and carried.

Report of Committee on Amendments to the Constitution.

THE PRESIDENT.—The next in order is the report of the Committee on Amendments to the Constitution. I will ask Mr. Whinery, the Chairman, to present this report.

SAMUEL WHINERY, M. AM. SOC. C. E.—I have not been able to see in the meeting Mr. Merriman, the Secretary of the Committee. Is Mr. Merriman here? If so, I would like him to present the report to the Society; if not, Mr. President, I suggest that the Secretary of the Society read the report, as it has already been issued to the membership.

THE PRESIDENT.—The Secretary will read the report.

REPORT OF COMMITTEE ON AMENDMENTS TO THE CONSTITUTION.

At the Business Meeting of the Annual Convention of the Society, held on the 27th day of June, last, the following resolution was adopted:

"That the proposed amendments be referred back to the Committee for further consideration and report, with instructions to place such report in the hands of the Secretary at least sixty days prior to the Annual Meeting, so that copies of it may be sent to the membership in advance of that meeting."

In accordance with this resolution the Committee resumed consideration of the matter thus recommitted to it, and now submits the following report, which may be considered as supplementary to its previous report.

The Committee has taken note of, and has given careful consideration to, the discussion at the Annual Convention relating to the amendments then proposed by it, and has re-examined the whole subject in the light of the criticisms and suggestions then offered, and now recommends that the Constitution be amended as follows:

Strike out the whole of Article II, and substitute for it the following:

ARTICLE II.—MEMBERSHIP.

Sec. 1.—The membership of the Society shall be classified as follows:

Honorary Members, Members, Associate Members, Associates, Juniors, and Fellows.

Report of Committee on Amendments to the Constitution (continued).

2.—The Members and Associate Members shall constitute the Corporate Membership of the Society.

3.—A Corporate Member shall be a Civil, Military, Naval, Mining, Mechanical, Electrical, or other professional Engineer, an Architect or a Marine Architect.

4.—A Member shall be not less than thirty-three years of age; shall have been in the active practice of engineering for at least ten years; shall be qualified to design and direct engineering works; shall have had responsible charge of engineering work of importance for at least five years, and shall have attained honorable standing in the profession. Graduation from a school of engineering of good reputation shall be considered equivalent to two years of active practice. The performance of the duties of a professor of engineering in any of its branches in such a school shall be considered equivalent to active practice.

5.—An Associate Member shall be not less than twenty-five years of age; shall have been in the active practice of engineering for at least six years, and shall have had responsible charge of engineering work of importance for at least one year. Graduation from a school of engineering of good reputation shall be considered equivalent to two years of active practice. The performance of the duties of a professor of engineering in any of its branches in such a school shall be considered equivalent to active practice.

6.—An Honorary Member shall be a person of acknowledged eminence in some branch of engineering or the sciences relating thereto. There shall be not more than twenty Honorary Members at any one time.

7.—An Associate shall be one who by scientific acquirements or technical experience has attained a position in his special pursuit qualifying him to co-operate with engineers in the advancement of professional knowledge and practice, although he may not be a professional engineer.

8.—A Junior shall be not less than twenty-one years of age, and his connection with the Society shall cease when he becomes thirty-two years of age, unless he shall have been transferred to another grade of membership. He shall have been in the active practice of engineering for at least two years, or he shall have been graduated from a school of engineering of good reputation. The status of Juniors elected prior to March 4, 1891, is not changed by the provisions of this Section.

9.—A Fellow shall have contributed to the permanent funds of the Society. After July 1, 1907, admission to the grade of Fellow shall be discontinued.

10.—Honorary Members, Associates, Juniors and Fellows shall be entitled to all the privileges of the Society except the rights to vote and to hold office. Corporate Members, elected to Honorary

Membership, shall not thereby forfeit their rights as Corporate Members.

Amend Sec. 2 of Art. III by inserting in the final clause, after the word "applicant," the words "possesses the necessary qualifications and"——. The clause will then read, "to show that the applicant possesses the necessary qualifications and is worthy of admission."

In reference to these amendments, the Committee wishes to supplement its previous report with the following remarks:

For the reasons stated in its former report, the Committee is still of the opinion that it is not expedient to change the present classification of the membership, or to change the present names of the several grades.

The Committee recognized from the first the desirability of having in the Constitution an accurate and adequate definition of the term, Civil Engineering, and devoted much careful thought to the matter. The appropriate place in the Constitution for such a definition is obviously in Art. I. The resolution appointing the Committee and fixing the scope of its work, seemed to confine its consideration to matters relating to membership alone, and the Committee did not feel that an amendment to Art. I could be considered as pertinent to the amendments referred to it. But a definition of civil engineering, or of the civil engineer, seemed essential in order to describe and limit correctly the boundaries of corporate membership, and the Committee, therefore, endeavored to incorporate such a definition in the provisions of Art. II.

The American Society of Civil Engineers has, from the first, held to the original broad interpretation of the term Civil Engineering, as a generic term, including the various branches now known by specific names such as mechanical engineering, mining engineering, electrical engineering, and others, and excluding only engineering devoted to purely military operations. The Society followed in this respect the lead and example of the oldest and most influential society of engineers in existence—The Institution of Civil Engineers of Great Britain—and the committee has assumed that our Society does not wish to change its position on this point.

But the work of the civil engineer merges by almost imperceptible gradations into that of the trades and many of the common occupations of mankind, so that it is very difficult, if it be indeed possible, to frame any general definition which, on one hand, will be broad enough to cover the recognized legitimate field of the profession, and on the other hand, will clearly differentiate it from occupations or pursuits which are not considered civil engineering.

Report of Committee on Amendments to the Constitution (continued).

The classical and often quoted definition, by Tredgold, adopted by the Institution of Civil Engineers, is open to the objection that it logically includes manufacturers, farmers and many other classes of people, since clearly they are often engaged in the scientific or practical work of directing the great sources of power in Nature for the use and convenience of man. The committee was not able to find, or to devise and to agree upon, a satisfactory brief definition which might be appropriately used in stating in general terms the professional qualifications for Corporate Membership, and before its previous report, abandoned the attempt. The discussion at the Annual Convention indicated, however, that such a definition is felt by the membership to be important, and it may be stated that the matter has occupied a large part of the attention and work of the Committee since the amendments were recommitted to it. Failing to agree upon any concise and satisfactory form of statement for such a definition, the Committee has reluctantly returned to substantially the language of the present Constitution, which designates the branches of the profession from which persons shall be eligible for Corporate Membership. It may be stated that no member of the Committee feels satisfied with this form, and it was adopted only after the failure of efforts to devise a satisfactory definition of civil engineering acceptable to even a majority of the Committee.

The discussion at the Annual Convention disclosed a difference of opinion as to whether certain professional classes, namely, Architects and Military Engineers, should be admitted to Corporate Membership. The right of the Society to exclude these classes is unquestioned, but the wisdom of doing so is at least open to the gravest doubt.

In the view of the Committee, the Society is primarily an organization for the professional improvement of its members, rather than a guild in which one of the objects of membership is benefit from a business point of view, and, while it is undesirable to admit persons or classes not in harmony with this primary object, it would be unwise to restrict Corporate Membership to civil engineers, in the narrower signification of the name. It would be very difficult to frame any comprehensive definition of civil engineering that would wholly exclude Architecture and Military Engineering, as these terms are now understood. In the present status of the Society, with its established reputation for wise conservatism, it is believed there would be less danger to its best interests in broadening than in narrowing the limitations of Corporate Membership.

It was suggested in the discussion that many architects are little more than decorators, and should, therefore, be classed with artists rather than with civil engineers. If this be true, it may be said in reply that such persons could not be admitted to

Corporate Membership, under even the most liberal interpretation of the requirements of the Constitution, for the grades of Member and Associate Member. The Board of Direction may, it would seem, be safely depended upon to draw the necessary distinction between what is and what is not the engineering element in architecture. It was suggested that architects might be more appropriately admitted to the grade of "Associate" in the Society. This grade was designed to form a working connection between civil engineers and those who by scientific acquirements or practical experience have attained a position in their special pursuits qualifying them to cooperate with engineers in the advancement of professional knowledge and practice. It was evidently intended that only persons ineligible for Corporate Membership should be admitted to this grade, since the present Constitution seems to exclude from it those who are professional engineers. To relegate architects to this grade would practically be to read them out of the profession of engineering. The Society can hardly afford to take this position. It is very doubtful whether any considerable number of the worthy members of that profession would care to join the Society in the subordinate grade of "Associate," and it is, therefore, most probable that such a change as that suggested would result practically in the exclusion of architects from the Society. These observations apply in some degree to marine architects, whose work is, in the main, unquestionably engineering design and construction.

In regard to the Military Engineer, it may be said that the distinction, originally, between Civil and Military Engineering has largely disappeared. In this country, at the present time, the only class to which the term Military Engineer can be appropriately applied is made up of the members of the Engineer and Ordnance Corps of the U. S. Army. The members of the Engineer Corps are engaged for the greater part of their time upon work which is distinctly Civil Engineering. Even when their duties relate exclusively to military projects, such as the construction of forts and of military bridges, the purpose rather than the character of the work, distinguishes it from civil engineering. In like manner, a large part of the work of the members of the Ordnance Corps is distinctly Mechanical Engineering of a high order, and admission to the Society from this corps has been based, heretofore, on meritorious work of that character. The Committee does not understand that it is the desire of the Society to shut its doors against the members of either of these corps, and it is not aware of the existence of any other engineers in this country to whom the term military engineer is appropriate.

The discussion at the Annual Convention developed some vigorous opposition to the clause proposed at that time which required that a Member "shall have attained a recognized position of honor-

Report of Committee on Amendments to the Constitution (continued).

able high standing in the profession." It also indicated that the Committee failed to make sufficiently clear the reasons which seemed to warrant the insertion of this clause, or else that the meaning of the clause was misapprehended.

The Committee did not anticipate that the meaning and intent of the clause would be open to misconception, and certainly did not intend that it should relate to fortuitous or popular reputation. It is to be remembered that in the application of this requirement the candidate will be judged by his fellow engineers alone, than whom no class of men is better able to discern and to value properly factitious reputation, or more ready to recognize and to concede true professional merit.

The Committee believes that there is a strong sentiment in the Society in favor of raising the standard for admission to the grade of Member, and it has given careful consideration to the question how this may best be accomplished. The age of admission and the time engaged in professional practice might be advanced, but these qualifications supply no adequate measure of an engineer's professional capacity; and to raise these requirements very materially might exclude men who in more important requisites are fully eligible. It does not seem to the Committee wise to raise the age of admission above 33 years, or to increase at all the other time stipulations. To raise the other requirements and to state them with sufficient definiteness to make them something more than matters of opinion is found to be so difficult that it may be said to be almost impossible.

Under these conditions the most practicable course would seem to be to supplement such requirements as it is possible to state, by a general requirement based upon the reputation of the applicant for engineering ability, as judged by his professional associates.

The present Constitution prescribes certain definite and unmistakable requirements for admission to the grade of member: the applicant must be at least thirty years old and must have been in the practice of his profession for at least ten years. It also stipulates certain other requirements that are more or less indefinite: he must have had responsible charge of work for at least five years. and he must be qualified to design as well as to direct engineering work.

What constitutes "responsible charge of work?" The Board of Direction holds it to mean "the direction of work under such circumstances that one may be called upon to use skill and judgment in meeting unforeseen conditions." Without presuming to criticise this definition, it may be safely asserted that there is hardly a Junior in the Society who has been at professional work for a few years, and has discharged his duties satisfactorily, who has not

often met and complied with this requirement. The Board doubtless adopted this definition because it found it impossible to frame a more accurate one that would fit the many varying conditions. More or less "responsible charge" is involved in the work of any engineer, whatever his professional attainments and skill may be, and there are so many gradations in the degree and character of responsibility that it is practically impossible to fix upon any definite measure which will meet the requirements of the Constitution. The subordinate engineer upon one work may be burdened with a greater weight of responsible charge than the chief engineer on another. Between the responsibility of the engineer who constructs or maintains a logging or mining tramway a few miles long, and that of the one who, perhaps not a whit more honorably and successfully, constructs or maintains a great trunk line railroad, there is obviously a wide range. Strictly construed, however, one is as much in responsible charge as the other. What the Board of Direction very properly takes into consideration in the practical application of this requirement is the character and importance of the responsibility involved. It is a matter of judgment based upon the ascertainable facts, and these facts, in the aggregate, are elements in the professional reputation of the applicant.

The requirement that the applicant must be qualified to design as well as to direct engineering work is also indefinable in exact terms. The ruling of the Board, that qualification to design "is to be proved by actual performance, by having added something of some importance to the actual engineering work done in the world," is itself indefinite. Assuming that all the facts are obtainable, the question of what constitutes importance in the work designed must in many cases be a matter of opinion. Neither is the qualification to direct engineering work susceptible of definite gradation.

The fact seems to be, then, that of the present requirements for admission to the grade of Member, two only are definite—age and length of professional service—and neither of these offers a satisfactory measure of an engineer's professional knowledge or skill, or of his fitness for admission to the highest grade of membership. The others are so indefinite that in practice the Board, in considering applications, and the Society in voting upon the question of admission, must rely largely upon the professional reputation of the applicant, as evidenced by the historical facts of his career.

The distinction between the grade of Associate Member and that of Member should involve something more than the elements of age, length of professional service and other qualities that may be definitely measured and stated. The grade of Member may, in a measure, be considered an honorary degree, denoting that the engineer upon whom it is conferred has, in the opinion of his fellow

Report of Committee on Amendments to the Constitution (continued).

engineers, won by merit a position of some honor and distinction in the ranks of the profession. This opinion must necessarily be founded upon the professional knowledge and skill he has displayed, and the character and extent of the work he has accomplished, or, in other words, upon the professional reputation he has built up among his fellow engineers.

The reasons above stated seem to the Committee to warrant the retention in a slightly modified form, of the requirement that candidates for the grade of Member shall have "attained honorable standing in the profession."

The arguments in favor of the other amendments now recommended were given in the previous report of the Committee, and as no serious objection to these was expressed at the Convention, they need not be considered further in this report.

Respectfully submitted,

S. WHINERY,
ALFRED NOBLE,
ONWARD BATES,
MORRIS R. SHERRERD,
SAMUEL E. TINKHAM,
THADDEUS MERRIMAN,
Committee.

THE SECRETARY.—There is a minority report, signed by Mr. Trautwine, who is here.

THE PRESIDENT.—The chair will interrupt this matter for a moment—the time for closing the ballot for officers has arrived. If there are any members who wish to vote, their ballots will now be received.

The chair declares the ballot for officers closed.

The next matter is the Minority Report on Amendments to the Constitution. Mr. Trautwine made that report; I think he is present.

John C. Trautwine, Jr., Assoc. Am. Soc. C. E., presented the following report:

MINORITY REPORT.

The undersigned, a minority of a Committee, to which were referred certain proposed Amendments to the Constitution, respectfully reports:

That he finds himself compelled to differ with his fellow members on the Committee in five matters of some importance, namely:

(1). In Sec. I, Art. II, the use of the term "Members" to signify only the members in the highest grade; while, elsewhere in the Constitution, the same term is used to signify members of all grades;

(2). The proposed wording of Sec. 3 of Art. II;

(3). In Sec. 4, Art. II, the raising of the lower age limit from 30 to 33 years;

(4). In Sec. 4, Art. II, the requirement that a Member "shall have attained honorable standing in the profession";

(5). In Sec. 7, Art. II, the use of the words "although he may not be a professional engineer."

Referring to these several points of difference, the undersigned would recommend:

(1). That Sec. I of Art. II, be made to read as follows:

Sec. 1.—The membership of the Society shall be classified as follows:

Honorary Members, Senior Members, Associate Members, Associates, Juniors, and Fellows.

Sec. 1 of Art. II, as proposed by the Committee, follows the Constitution as at present worded, in using one and the same word, "Members," to designate (1) all members of the Society (or at least all Corporate and Honorary Members), and (2) members of the highest class.

It is plainly unfortunate to use one and the same word to designate two distinct ideas, one of these ideas including the other. No authority, however respectable, can justify such abuse of language.

The undersigned suggests that some qualifying term be used in connection with the word "Member," when used to indicate the highest class of membership in the Society; and that the word "Senior" is a suitable term for this purpose.

(2). For Sec. 3 of Art. II, as recommended by the Committee, read:

Sec. 2.—Corporate Members shall be persons who are, or who have been, engaged in the profession or work of civil engineering in its broad sense, including its several branches, such as those commonly known as Civil, Mining, Mechanical, and Electrical Engineering.

The section, as proposed by the undersigned, has the merit that it makes eligible to Corporate Membership those who have qualified themselves for such membership by being, or by having been, engaged in the profession or work of civil engineering, by whatever term their particular branch of the profession may be called. It thus avoids the necessity of making out a catalogue of those branches, a catalogue which must always be liable to the necessity of amendment by the addition of newly created titles, or otherwise.

To undertake to furnish such a catalogue thus subjects the Society to the risk of giving unintentional offense to the members of some class of engineers, the name of which does not appear in the catalogue.

The Committee carefully sought to avoid all possible offense to

Report of Committee on Amendments to the Constitution (continued).

members of such branches, and the undersigned submits his proposed substitute as a means of avoiding such offense, making Membership depend, not upon the title assigned to, or assumed by, the applicant for membership, but upon the past or present activity of such applicant.

(3). Sec. 4.—To raise the lower age limit from 30 to 33 years, would deprive the Society of three years' membership of many men richly entitled to it.

(4). In Sec. 4, the requirement that "A Member shall have attained honorable standing in the profession," while no such requirement is made in the case of members of other classes, implies that members of those classes need not have attained honorable standing in the profession.

The undersigned fully agrees with his fellow members as to the desirability of inserting some such clause, but he submits that the clause here used, if used at all, should be so used as to cover all grades of membership.

He believes that some additional qualification of this sort should be required of members of the highest grade, and he would suggest that, in the case of members of that grade, the word "high" should be introduced, making the additional requirement, for that grade, read: "Shall have attained high standing in the profession."

(5). The Constitution, in its present form, requires, in Sec. 5 of Art. II, that "An Associate shall be a person who * * * has attained a position * * * qualifying him to co-operate with engineers * * * but who is not a professional engineer."

This last clause has been taken as meaning that no professional engineer is eligible as an Associate; and the Committee, at the suggestion of the undersigned, amended the last clause to read: "although he may not be a professional engineer."

This obviated the difficulty just mentioned, but the undersigned now sees that this amendment leaves the section in bad shape rhetorically, and makes it fail of its purpose; for the section, as suggested by the Committee, provides in effect that "An Associate, although he may not be a professional engineer, shall be one qualified to co-operate with engineers;" whereas the intention of the section doubtless is that one qualified to co-operate with engineers shall be eligible as an Associate, although he may not be a professional engineer.

The undersigned submits that both clauses may be obviated by simply erasing the words, "although he may not be a professional engineer."

As a matter of minor importance, the undersigned suggests such rearrangement of the sections that the following provision may be stated once for all as applying both to members of the highest grade and to Associate Members.

"Graduation from a school of engineering of good reputation shall

be considered equivalent to two years of active practice. The performance of the duties of professor of engineering in any of its branches in such a school shall be considered equivalent to active practice."

All of which is respectfully submitted.

JOHN C. TRAUTWINE, JR.

THE PRESIDENT.—I am going to ask those members who are standing in the rear if they will kindly take seats. We will have to keep quiet during the discussion of matters.

You have heard the report of your committee and also the report of the minority of the committee on the proposed amendments to the Constitution. What is your pleasure?

MR. FISHER.—I move that the reports be accepted.

MR. NORTH.—The effect of that motion would be that both reports would come up for discussion. If there is any doubt about it, for a vote——

MR. FISHER.—I move that both reports be accepted.

THE PRESIDENT.—That the report of the committee be accepted and the report of the minority be accepted, which would bring the matter before the meeting for discussion. Those in favor of the motion will say "aye;" opposed, "no." Carried. The reports are accepted and they are now before the meeting.

THE SECRETARY.—I have two or three written communications from gentlemen who could not be here. Perhaps it would be well to read them first.

The Secretary read the following letters:

Discussion on Amendments.

10 Victoria Street,
WESTMINSTER, S. W., Dec. 8, 1906.

C. W. HUNT, ESQ.,
Sec., Am. S. C. E.

DEAR SIR:—While favoring in general the amendments to the Constitution as drafted by the Committee, I desire to put on record my protest against the substitution in Art. II, Sec. 7, of the words "although he may not be a professional engineer" for "but who is not a professional engineer." It seems to me essential that engineers should be excluded from the class of Associates. Surely any one who is an engineer and otherwise desirable can find his place either among Members, Associate Members, or Juniors, and to admit him as Associate is simply to allow him to enjoy most of the privileges of the Society while evading a portion of the dues.

With best wishes, and regretting that I cannot be at the Annual Meeting,

Yours truly,

M. E. YEATMAN.

Discussion on Amendments. (continued).

CHALON S. SAÔNE, Dec. 28, 1906.

CHAS. WARREN HUNT, ESQ.,
Secretary, Am. Soc. C. E.

DEAR SIR:—The circular of Nov. 23d, 1906, has reached me here. I would like to offer some suggestions along the lines I have for several years advocated in regard to membership in the Society. The scope of the Society in work and membership should be broader and less restricted, as the work of the Engineer is constantly broadening and including on almost every large work the various classes of work referred to in the majority's definition No. 3 of a "Corporate Member."

For example, the port which, as Consulting Engineer, I am preparing to build at Para, Brazil, embraces civil, mechanical, electrical and even mining engineering, if provision for handling coal comes under the latter head. Why should there be any distinction made between these branches of civil engineering? We may any day have new names added to the classes of Civil Engineering; and therefore I am in favor of abolishing all distinction, and let it be understood that "Civil Engineering" embraces all professional engineering except "Military." In other words, adopt the principle and methods of the Institution of Civil Engineers of London, where, when once inside the walls, all members are "Civil Engineers"—whether they be Hawkshaws, or Whites, or Preeces, or Kennedy, or Fox's, or Barrys—whether they manage the telegraph services of Great Britain, or build the warships or mercantile vessels, or are proficient in chemical engineering, or in any other way utilize "the great sources of Power in Nature for the use and convenience of Man.

My views on this subject have often been expressed to the Society, and I need not repeat them.

I would therefore suggest that the phraseology of Mr. Trautwine for Sec. 2 be as follows, and be adopted:

"Corporate Members shall be those who are or who have been engaged in the professional work of Civil Engineering in its broad sense."

I am sure that the definition of a "Corporate Member," as given by the Majority is not correct, for it distinctly includes "Military," and the Military Engineer is a "professional Engineer," and yet, in the last paragraph of page 3, those engineers devoted "to purely military operations" are excluded, as they ought to be in a "Civil Engineers" Society—as is done by the Inst. C. E. By including "military" in the definition, the Society is not following "in this respect the lead and example of the oldest and most influential Society of Engineers in existence—The Institution of Civil Engineers of Great Britain."

In other respects, I am of the opinion that the views of the majority are correct, although the criticism of Mr. Trautwine in reference to the term "member" is proper, and, could a more distinctive title be found and more definite, it would be well to adopt it, although I do not like the word "senior."

I am yours truly,

E. L. CORTHELL, M. AM. SOC. C. E.

Jany. 12, 1907.

MR. C. W. HUNT,
Secy., Am. Soc. C. E.,
New York City, N. Y.

MY DEAR MR. HUNT:—I do not know whether it is proper or parliamentary to discuss the proposed amendment to the Constitution by letter, but I wish to strongly urge that the last sentence of Sections 4 and 5 of Article II shall read: "The performance of the duties of a professor of engineering in any of its branches in such a school shall be considered equivalent to active practice in charge of engineering work."

I think it ill becomes this society to fail to recognize, much less to put a slight upon, members of the teaching profession; and I believe that a man who is qualified to hold the position of professor of engineering in a technical school of recognized standing is a man who would be a desirable member of the society. Some teachers are by virtue of their location unable to do much in the way of practical or consulting work, but they may nevertheless do some, and they may by study, investigation and experiment be thoroughly equipped with knowledge and judgment on important branches of the profession. Many professors do consulting work, but cannot be said to be in charge of work, and I fail to see why a man who has had charge of laying a few miles of railroad track or sewer work should be given a standing higher than that of a man who has perhaps been his teacher and to whom he owes very likely a great part of his success.

As the Constitution stands, a young man only a few years out of college is eligible for membership, while his professor, who may be twenty years older and possessed of infinitely greater knowledge and judgment, although not of actual experience in the details of constructive work, is not eligible.

It is hard enough now to induce good men to go into the teaching profession, and it is going to be harder still if the status of teachers is not in some way improved. The establishment of the Carnegie Foundation is a great step in this direction, by assuring to a man who devotes his life to the arduous and unremunerative profession of teaching a competency for his declining years. I

Discussion on Amendments (continued).

know of teachers who have been refused admission to this society who would in every way have been an ornament to its membership. I know of others who would not apply for admission because they did not wish to run the risk of being rejected. Naturally, a teacher who has confidence in himself and his work does not desire to take a secondary place in his professional society. Full membership is none too good for him.

The proposed amendment makes architects and military engineers eligible for admission to the society, and I desire to quote here from the report of the majority of the Committee. They say:

"The discussion at the Annual Convention disclosed a difference of opinion as to whether certain professional classes, namely, Architects and Military Engineers, should be admitted to Corporate Membership. The right of the Society to exclude these classes is unquestioned, but the wisdom of doing so is at least open to the gravest doubts.

"In the view of the Committee, the Society is primarily an organization for the professional improvement of its members, rather than a guild in which one of the objects of membership is benefit from a business point of view, and, while it is undesirable to admit persons or classes not in harmony with this primary object, it would be unwise to restrict Corporate Membership to civil engineers, in the narrower signification of the name. It would be very difficult to frame any comprehensive definition of civil engineering that would wholly exclude Architecture and Military Engineering, as these terms are now understood. In the present status of the Society, with its established reputation for wise conservatism, it is believed there would be less danger to its best interests in broadening than in narrowing the limitations of Corporate Membership."

It appears to the writer that the case of the engineering professor is much stronger even than that of the architect and military engineer. The professor is certainly in as close touch with engineering work as most members of the professions referred to. However, if the society is "primarily an organization for the professional improvement of its members," a professor of engineering should not be excluded, but should rather be welcomed.

GEO. F. SWAIN.

President, American Society of Civil Engineers.

DEAR SIR:—The undersigned begs leave to offer the following suggestions to be read in discussion of proposed amendments to the Constitution at the Annual Meeting:

Change the proposed amendments as now recommended by Mr. Whinery's Committee by striking out Sections 4, 5 and 7, and substitute for them the following:

4.—"A Member shall be not less than thirty-three years of age; shall have been in the active practice of his profession for at least

ten years; shall be qualified to design and direct engineering works; shall have had responsible charge of engineering or architectural work of importance for at least five years, and shall have attained honorable standing in his profession. Graduation from a school of engineering of good reputation shall be considered equivalent to two years of active practice. The performance of the duties of a professor of engineering in any of its branches in such a school shall be considered equivalent to active practice."

5.—"An Associate Member shall be not less than twenty-five years of age; shall have been in the active practice of his profession for at least six years, and shall have had responsible charge of engineering or architectural work of importance for at least one year. Graduation from a school of engineering of good reputation shall be considered equivalent to two years of active practice. The performance of the duties of a professor of engineering in any of its branches in such a school shall be considered equivalent to active practice."

7.—"An Associate shall be one who by scientific acquirements or technical experience is qualified to co-operate with engineers in the advancement of professional knowledge and practice, although he may not be a professional engineer."

The changes made are in the second, fourth and sixth lines of Section 4, in the second and third lines of Section 5, and in the third and fourth lines of Section 7.

In support of these changes, it may be said that, if Article II of the Constitution is to be amended at all, an effort should be made to perfect the wording so as to make the purpose clear and leave no room for doubt.

Now, by the use of the word "engineering" in certain lines of Sections 4 and 5 of amendments proposed by Committee, under a strict construction, architects would be excluded from Corporate Membership, excepting when the architect had been doing actual engineering work.

It is nowhere stated that architecture and engineering are one and the same. In fact, Section 3 clearly implies that architects are not professional engineers.

The meaning of Article II is, therefore, not as clear as it should be, Section 3 admitting the architect, while Sections 4 and 5 all but deny him admission. By changing the wording as suggested the meaning as regards architects will be made clear while the effectiveness is in no way diminished.

In Section 7 the old wording not changed by the Committee makes it appear that the candidate's position is the important factor. By the change suggested it will be a question of technical qualifications only, which would certainly seem preferable.

The position in his special pursuit which the candidate has at-

Discussion on Amendments (continued).

tained may be taken as evidence as to his technical qualifications, but need not be made the crucial test.

Respectfully submitted,

S. Bent Russell,
M. Am. Soc. C. E.

St. Louis, Jan. 14th, 1907.

The President.—The matter is now open for discussion.

Mr. Whinery.—Mr. President, I assume that there will be more or less discussion of this report and of its details, and, in order that it may be considered in detail, I move that the several sections be taken up *seriatim*.

The President.—In order to save time, the chair will state that that will be the course of procedure, unless some objection is made.

Mr. Whinery.—Then, Mr. President, I move that Section 1, Article II, as proposed by the Committee be adopted and sent out to letter-ballot.

Motion seconded.

The President.—It is moved and seconded that Section 1 of Article II be adopted and sent out for ballot. Any discussion on this question?

Mr. Lowinson.—Mr. Schneider has drawn my attention to one point in connection with this discussion, and that was that marine architects——

The President.—This relates only to Section 1 of Article II.

Mr. Lowinson.—Very good.

The President.—Those in favor of adopting Section 1 as reported by the Committee and sending it out to letter-ballot will say "aye;" opposed, "no." Carried.

Mr. Whinery.—Section 2 of Article II is practically not changed from the previous Constitution, and I suppose there is no question about the propriety of adopting it, but I take it that it is necessary to put it before the meeting. I make the same motion in reference to Section 2.

The President.—The same motion has been made in respect to Section 2 of Article II, as to Section 1. Those in favor of the motion will say "aye;" opposed, "no." Carried.

Mr. Whinery.—I move that Section 3 of Article II, as proposed by the Committee, be adopted and forwarded to letter-ballot.

Motion seconded.

The President.—It is moved and seconded that Section 3 of Article II be adopted and sent out for letter-ballot.

W. J. Baldwin, M. Am. Soc. C. E.—If it is in order, I will move that the word "architect" be stricken from Section 3, and

I will say that I am an Associate Member of the Architects' Association.

THE PRESIDENT.—The chair has not heard the motion seconded.

Motion seconded.

THE PRESIDENT.—The motion is seconded. It is now open for discussion.

MR. BALDWIN.—The American Institute of Architects would object to being called a guild, just as much as the American Society of Civil Engineers. Now, as a matter of fact, they are very particular to exclude all but men who have risen very high in the architectural profession from full membership, and they exclude engineers from full membership, unless they can in some way call themselves architects.

Going beyond the fact that they exclude civil engineers and other engineers from full membership in their organization, the relation of architects and engineers is becoming peculiar. The architect to-day is cutting out the engineer on all his enterprises, and the engineer has to look to the architect, in New York and other big cities, actually for his employment in many of these great enterprises, and there are cases to-day in New York City, that I am perfectly familiar with, wherein the architect makes the contract, receives the commission of 5% for himself, receives a commission of 5% for the engineer, and offers him 2½%—and offers him less.

I presume that the subject is well enough known to a great many here, and I have said enough upon the subject. The facts remain. Take our great bridges. There is an association here—I forget its name—to which all the designs of public buildings have to be submitted; the designs of bridges have to be submitted to it; and these men come in and criticise the engineering work, and, until they approve of it, the engineer cannot go ahead with the scheme.

Now, I think it is worthy of consideration as to whether or not the unqualified architect should be a member of this Society, when a member of this Society cannot be a member of the American Institute of Architects.

If a man only builds a house that is worth but $5 000, from a set of plans that he buys from the Scientific American for $25, he puts up a shingle as an architect, and in a little while he becomes a member of the Architects' Society, and because he is a member of the Architects' Society he becomes a member of the American Society of Civil Engineers, and thus people get into our Society who are not eligible as engineers. They have no engineering qualifications; and where we put a high standard on engineers we put a very low standard on men who come in through this side door.

Discussion on Amendments (continued).

MR. ALLEN.—As counteracting what one side has set forth, I would say that there has been some improvement at times from the fact that nowadays, occasionally, the engineer employs the architect and expects the architect to do the artistic work. I hope we shall find more of them in the future.

MR. NORTH.—I would like to say that this Society was originally organized as The American Society of Civil Engineers and Architects. While we were domiciled in William Street, along in seventy odd, the late Julius W. Adams, Past-President, Am. Soc. C. E., read a paper in which he maintained that an architect was a decorator and not an engineer, and, by a vote of this Society, the word "Architect" was stricken from our title, and we became The American Society of Civil Engineers; but at no time, as far as I know, has there been any exception taken to architects who knew enough to design a stable building, entering this Society. It seems to me that we can trust the Directors of the Society to exclude mere decorators and only admit architects who know something of stability.

MR. LOWINSON.—Mr. President, and gentlemen, bearing out the suggestion of Mr. North, it has been my intention to suggest an extra section to this article giving the Board of Direction authority to interpret the meaning of the terms used in this section. The trend of the discussion caused me to feel that possibly that might be necessary, and, while my intention was to suggest something of the kind, I hardly think it is in order to discuss a point of that kind at the present time. I just want to draw attention to something that Mr. Schneider mentioned to me, and that is the words "Marine Architects," the last words of Section 3. As I understand it, the classification of the marine profession to-day, in reference to engineering, is naval architects and marine engineers, and I therefore move, unless there is some objection to it——

THE PRESIDENT.—The question before the Society at present is the omission of the word "architect." The discussion is now on the amendment proposed by Mr. Baldwin.

MR. LOWINSON.—I did not know that a motion was before the meeting.

MR. SCHNEIDER.—Will Mr. Baldwin accept my amendment? I have an amendment to offer which will probably be the same thing as Mr. Baldwin's motion to leave out the word "architect." I make a motion, if Mr. Baldwin will accept it, to change Section 3 to read as follows: "A Corporate Member shall be a professional engineer practicing any branch of the profession."

THE PRESIDENT.—The question is whether the maker of that motion desires to accept it?

MR. BALDWIN.—Yes; I will; that relates to the whole clause.

THE PRESIDENT.—If there is consent from the Society, the amendment will be the one suggested by Mr. Schneider and accepted by Mr. Baldwin as a substitute.

MR. CHESTER.—I liked the decision of the chair a while ago that this Society was not bound to any set of rules to such an extent that we could not go on and transact business. We have often been confronted with the difficulty that our own ideas have been wrongly interpreted by laymen. In fact, if laymen could properly interpret the rules and regulations laid down by engineers for the explaining and building of their works, we would not have any need of engineers. On the other hand, if we try to make up a set of rules for admission here too exact, we will have no use for a membership committee. We have always tried to have at all times a very efficient Board of Direction, and acting under that the Membership Committee. What is the use of wasting our time at this meeting by trying to get up such an exact set of rules that there will be no use for a Membership Committee, or of referring anything to the Board of Direction for the election and selection of our membership?

MR. BALDWIN.—I feel that if Mr. Schneider's motion is adopted, it will leave it in the position that the gentleman suggests; it leaves it entirely in the hands of the Membership Committee. This makes it obligatory as to the admission of architects, and if any man who builds a little wooden building or anything else, and puts out a shingle, becomes an architect, and he asks admission to the Architects' Association and gains it, and is in a position to ask for admission to the American Society of Civil Engineers, he will not be rejected. It is not at all fair to men who are educated as civil engineers, and to other kinds of engineers, to have others enter by this side door, because it is a side door, and does not apply to architects alone, but to a great many other professions that I am not going to mention in this particular motion. Therefore, I say, you are in favor of the motion of Mr. Schneider.

W. W. CREHORE, M. AM. SOC. C. E.—The question is on Mr. Schneider's amendment, which practically amounts to omitting the words "Architect" and "Marine Architect." I am not in favor of doing that. If the following two sections, 4 and 5, shall be strictly enforced by the Board of Direction, no architect can get into the Society as a Corporate Member unless he is also an engineer; and I do not see how the wording of Section 3 could stand. An architect is also an engineer—he cannot come in. An architect is not an engineer. We have a grade in which he can be admitted as an Associate. You will find that is the fact, it seems to me.

GEORGE A. SOPER, M. AM. SOC. C. E.—Is it proper to suggest to Mr. Schneider and the other gentlemen a substitute for the present motion which they have proposed?

Discussion on Amendments (continued).

THE PRESIDENT.—Yes.

MR. SOPER.—The idea is not to bring in any novel form, but to urge that suggestions made by the minority of the committee be adopted so as to read this way. It occurs to me it will meet the views, perhaps, of all of us, and the views of persons who have spoken. "Corporate members should be persons who are or have been engaged in the profession of civil engineering in its broad sense." I have a word to say on that if it is a proper time to say it.

THE PRESIDENT.—The only way in which that can be brought before the Society is by the acceptance on the part of those who have made another motion at the present time. Until those motions are acted upon, it would come up later.

MR. SOPER.—Is it necessary to go through the formality—would an informal consent be sufficient?

THE PRESIDENT.—I think consent on their part would be sufficient, according to the rules enforced. I have not heard their consent, and unless they express it we will have to take action on their amendments.

MR. SOPER.—In order to lead them, perhaps, to give a consent, I should like the privilege of referring to what has been written by a very eminent Past-President of this Society, the late George S. Morison. This was delivered as a presidential address in 1895 before the Society, and later elaborated as an oration delivered at Cambridge, and eventually incorporated in a series of essays and addresses termed "The New Epoch," and published after Mr. Morison's death.

"It is a common error to think of civil engineering as a coördinate branch of a general profession with many other branches; to class it with mechanical engineering, with hydraulic engineering, with sanitary engineering, with mining engineering, with electrical engineering, or with any other specific branch. The name of every special branch of engineering has a distinctive meaning; the mechanical engineer deals with machines; the hydraulic engineer, with water; the mining engineer, with mines; the sanitary engineer, with drainage; and the railroad engineer, with railroads. The word "civil" has no such distinctive meaning; it shows only that civil engineering is the work of the citizen and not the work of the soldier. Civil engineering, in its true meaning, embraces every special branch of engineering. The professional limitation which should be applied to the civil engineer is that he must be a man who in his own department can design as well as direct. He must have that control over his work which nothing but intelligent knowledge of the subject gives. He may be a railroad builder, he may be a skillful surveyor, he may be a mechanical engineer, or he may follow any other specialty; but whatever he does he must do it not as a skillful workman but as one qualified

to design. Any man who is thoroughly capable of understanding and handling a machine may be called a mechanical engineer, but only he who knows the principles behind that machine so thoroughly that he would be able to design it or to adapt it to a new purpose, whatever that purpose may be, can be classed as a civil engineer. Any skillful sewer-builder and pipe-fitter may claim to be a sanitary engineer, but only the man who approaches his work with the intelligent knowledge of the conditions which sanitation involves can be classed as a civil engineer."

It seems to me that if we could agree to accept those definitions of Mr. Morison's, no doubt they would meet the views of many of us, and could adopt it and thus meet all views. Will you kindly ask in an informal way if the gentlemen will permit it?

THE PRESIDENT.—They have not expressed their willingness to accept, and therefore the motion is on the amendment as read by them. It is moved and seconded that the clause be changed to read: "A Corporate Member shall be a professional engineer practicing any branch of the profession." Is there any particular discussion on this particular motion?

MR. TRAUTWINE.—During the deliberations of the committee it was suggested that such wording might rule out veteran engineers who had ceased actively to practice their profession, although they might by their past practice be fully entitled to membership; and that is the reason that I said, "Persons who are or who have been engaged in the profession."

ARTHUR S. IVES, M. AM. SOC. C. E.—I would like to make an amendment to the present motion, that the minority report, as submitted by Mr. Trautwine for this section, be substituted for the present motion.

THE PRESIDENT.—It is moved, as an amendment to Mr. Schneider's amendment, that the section as presented by the minority be substituted for the section as presented by the committee.

GARDNER S. WILLIAMS, M. AM. SOC. C. E.—I would raise a point of order. A motion to substitute is in the nature of a motion to amend, and is so classed in most of the manuals, at least, and therefore it is out of order, being essentially a motion to amend an amendment to an amendment.

THE PRESIDENT.—I think it is not a motion to amend an amendment to an amendment. The motion that we have before us is simply an amendment to the first motion. It has been accepted by Mr. Baldwin, although it has been called Mr. Schneider's amendment. It is but an amendment, and not an amendment to the amendment.

MR. WILLIAMS.—Let me understand your ruling clearly. Mr.

Discussion on Amendments (continued).

President, which is, of course, justified. You are ruling that the amendment to the Constitution as proposed is a principal question, and is not to be looked upon as an amendment. That position is correct, and I will withdraw my point of order.

MR. CREHORE.—It seems to me that the word "practicing" in Mr. Schneider's amendment is hardly necessary; for that word I should leave out, and use the other phraseology, just as you use it, that is: "A Corporate Member shall be a professional engineer in any branch of the profession." It seems to me to cover the whole subject, being much shorter. The fact that he does not practice does not enter into it.

THE PRESIDENT.—The motion before the meeting is the substitute to Mr. Schneider's motion by adopting Mr. Trautwine's. Those who are discussing the question will kindly keep to that line.

MR. BALDWIN.—What is the amendment? I do not understand it.

THE PRESIDENT.—It is that the wording of this section as stated in the minority report by Mr. Trautwine be accepted as a substitute for Mr. Schneider's motion.

MR. IVES.—Would you mind having that read over again?

THE PRESIDENT.—Mr. Secretary, will you read it?

THE SECRETARY.—"Corporate members shall be persons who are, or who have been, engaged in the profession or work of civil engineering in its broad sense, including its several branches, such as those commonly known as Civil, Mining, Mechanical, and Electrical Engineering."

Mr. NORTH.—I would like to ask if the person who proposed this substitution would be willing to have Section 2 as proposed read thus: "Corporate members shall be persons who are, or have been, engaged in the work of civil engineering in its broad sense, including its several branches," stopping there. That is as near Mr. Schneider's idea as we can get. It would also provide for the men who have left the profession of civil engineering, like those who have become presidents of railroads and such things, persons who are well qualified to be members of this Society, but could not possibly be admitted under Mr. Schneider's resolution or amendment.

Mr. IVES.—I accept that.

THE PRESIDENT.—The mover of the substitute accepts the change as suggested by Mr. North, so that there will be omitted the words "such as those commonly known as "Civil, Mining, Mechanical, and Electrical Engineering." The question is on that amendment to the amendment as it has been modified.

GEORGE H. BENZENBERG, M. AM. SOC. C. E.—Are we not apt to confound matters a little in regard to Sections 3 and 4? Because a man is an architect it does not necessarily admit him to

this Society. The qualifications are in Sections 4 and 5, and if an architect can meet the qualifications stipulated in Sections 4 and 5, why then, the Board of Direction might consider him entitled to membership; but Section 3 in itself does not state anything in regard to the qualifications for membership. It simply enumerates such lines of professional engineering as shall be entitled to receive consideration, but the specifications as to just what he shall perform or the duties in the lines which he is following are laid down in Sections 4 and 5, and therefore it does not seem to me as vital or important as those which you enumerate under Section 3.

Mr. Whinery.—I am very glad that our coming President made those remarks. That is precisely the view that the Committee takes of the whole matter. The Committee regarded it as of some importance that the statement in Section 3 should be accurate, and should be satisfactory, but, in the view of the Committee, the fact that an architect, or, in fact, that a farmer, should be mentioned in this Article 3 makes no practical difference, because any farmer, as Mr. Benzenberg has stated, who can pass the requirements of Sections 4 and 5 would be fully entitled to membership in the Society.

It is desirable that some satisfactory general statement of the qualifications required for Corporate Membership should be made; and if the Society thinks well to adopt the phraseology in so far as it has been mentioned before the Society—the phraseology of the minority report—I think I may say for the most of the members of the Committee that they will heartily approve of it, and it will be quite satisfactory to them.

Mr. Crehore.—I do not know how far I will be allowed to go. I want to make a third amendment to the second amendment.

The President.—Not very far.

Mr. Crehore.—Addressing myself to this amendment: if we were to strike out the words "or work" in the second line of Section 2 of the minority recommendation, and also the words "in its broad sense" which seem to me to be superfluous, then we would have Mr. Schneider's motion, not quite so well expressed as Mr. Schneider has expressed it, with a slight trifling difference.

Frank W. Hodgdon, M. Am. Soc. C. E.—I would like to say that Section 3 is absolutely useless. Section 4 describes what a membership is; Section 5 describes what an associate membership is. Of what use is Section 3?

The President.—The section as proposed by Mr. Ives as a substitute for that proposed by Mr. Schneider does not commit the Society to this amendment as against the original motion. Those in favor of Mr. Ives' amendment to Mr. Schneider's amend-

Discussion on Amendments (continued).

ment will say "aye;" those opposed, "no." The chair is in doubt.

Mr. Ives' amendment was the adoption of the minority report as a substitute for Mr. Schneider's suggestion. Members who are in favor of the motion will rise.

A MEMBER.—What is the motion? Read it as it stands.

THE SECRETARY.—Mr. Ives has suggested, as I understand it, Mr. President, that this be substituted for the suggestion of Mr. Schneider: "Corporate members shall be persons who are, or who have been, engaged in the profession or work of civil engineering in its broad sense, including its several branches."

A MEMBER.—Question.

THE PRESIDENT.—Those in favor of the motion just made will rise.

THE SECRETARY.—(After making a count) 121.

THE PRESIDENT.—Those opposed. The amendment is carried.

THE SECRETARY.—There were twenty-four who stood up—some of them sat down.

THE PRESIDENT.—Mr. Ives' amendment has been substituted for Mr. Schneider's amendment. The question is now on this amendment as against the original motion of the committee, shall the third section proposed by the committee be amended by substituting Mr. Ives' motion? In order that it may be perfectly clear, it might be well to have both of them read.

THE SECRETARY.—The committee recommends the following:

"A corporate member shall be a Civil, Military, Naval, Mining, Mechanical, Electrical, or other professional Engineer, an Architect, or a Marine Architect."

Mr. Ives' motion was that this should be substituted:

"Corporate members shall be persons who are, or who have been, engaged in the profession or work of civil engineering in its broad sense, including its several branches."

THE PRESIDENT.—I will put the question.

CHARLES H. GRAHAM, M. Am. Soc. C. E.—I rise to a point of information as to whether the Society in adopting the motion last voted on has not voiced its sentiments, thereby making the question of a majority report unnecessary for further consideration.

THE PRESIDENT.—No; it has not.

A MEMBER.—Question.

THE PRESIDENT.—All in favor of the amendment as amended instead of the majority report will say "aye;" those opposed, "no." The majority report is amended by the substitution——

A MEMBER.—It is adopted now and it is ordered sent to ballot.

THE PRESIDENT.—It has not been ordered sent to ballot yet. The question now before the Society is shall the amended motion be adopted and sent out for letter-ballot.

MR. HODGDON.—It seems to me that this is so.

MR. WILLIAMS.—I will move to amend by striking out Section 3. Motion seconded.

MR. KNAP.—I hardly think that is in order.

MR. WILLIAMS.—And renumber the other sections.

THE PRESIDENT.—The same result can be reached, if the members do not wish to send this section out to ballot, by voting in the negative.

A MEMBER.—It is a definition of Corporate Members; it is not intended to define the engineer; but it is intended to define the Corporate Membership, in the Society, and it seems to me that it is in order to put it where it is.

MR. WHINERY.—I rise to a point of order. I think the two last motions made are out of order. My first motion was that Section 3 as proposed by the Committee be adopted and sent out to ballot. That motion was amended. That amendment was adopted, and the motion—the original motion—as amended was adopted. Therefore, the matter is settled and further amendment is out of order.

THE PRESIDENT.—The point of order is well taken. The question is now whether this section as amended shall be sent out to ballot.

MR. WHINERY.—I rise to another point of order. Has not this motion to send out to ballot already been adopted? The original order included that. The phraseology recommended by the committee is adopted and sent out to ballot. The phraseology was changed, but the other part of the motion providing that it should be sent out to ballot was not changed and was therefore adopted by the final vote. As I understand it, the section as adopted by the last vote is not only adopted, but ordered sent out to ballot, and the matter is closed.

THE SECRETARY.—May I say one word? The Constitution has a provision which tells how you are going to deal with these things. It is rather pertinent.

"Such amendments shall be in order for discussion at such Annual Meeting, and may be amended in any manner pertinent to the original amendments by a majority vote of the Annual Meeting, and if so amended shall be voted upon by letter-ballot in form as amended by the Annual Meeting; if not so amended, they shall be voted upon by letter-ballot as submitted."

THE PRESIDENT.—It is obvious that there is no further action needed, and it goes, in the course of events, to the members of the Society.

MR. WHINERY.—Taking the further sections in Article II, I move that Section 4 as recommended by the Committee—Section 4 of Article II—be adopted and sent out to ballot. I add that motion so that there will be no question about it.

Discussion on Amendments (continued).

Motion seconded.

THE PRESIDENT.—It is moved and seconded that Section 4 as recommended by the Committee be adopted.

MR. WILLIAMS.—There are two points in Section 4 that I wish to call attention to. Do we understand that we interpret the work which the young engineer or the student of engineering does immediately after coming out of college, when, perhaps, serving as a draftsman or rodman or instrumentman or chainman, or anything else, as practicing engineering? Now, if we do, it is all right, and there is no more to be said on that point, but it seems to me that it would be better to substitute the words "actively engaged in engineering work," rather than "the active practice of engineering," because, as I conceive engineering, it is something more than that which the student or the young embryo engineer performs during the first few years after he has come out of college.

In other words, I think that the adoption of this section in this form has a tendency to belittle the term "engineering," which I consider one of the most noble terms in our language. I would therefore move that Section 4, as proposed by the Committee, be so amended as to read—or be amended by striking out the words "in the active practice of engineering," and substitute therefor, "actively engaged in engineering work."

Now, while I am on my feet, I would like to indicate the other modification that I propose, although I shall leave my motion as it is for the purpose of having this point settled before we take up another. The second point I would raise applies to the last paragraph, the last sentence. It is along the lines of the discussion presented by Professor Swain. I, however, object to the language proposed by him, as there is no time limit in the language which he has presented, and I would incorporate his idea and modify his language as follows: "The performance for an equivalent time of the duties of a professor of engineering in any of its branches in such a school shall be considered as satisfying these requirements." As I say, I move the first modification.

THE PRESIDENT.—The matter before the meeting is the amendment to Section 4 of the Committee's report substituting the words "actively engaged in engineering work" for the words "in the active practice of engineering"—the amendment of Mr. Williams.

MR. SHERRERD.—This same wording has been used in the Constitution for a number of years, and has been practiced by the Board of Direction, and it seems to me that their interpretation along the lines suggested by Professor Williams has never been suggested heretofore, and it seems to me perfectly safe to leave it to the Board of Direction. If we use the words, "actively engaged in engineering," we will open the doors a little wider. Perhaps

some man who has had no training in engineering, who has been a rodman or a chainman, without any purpose of following up the profession of engineering, if he should suddenly conclude to take up civil engineering, will want to have his work, for three or four or five years before he started in to practice, counted as part of his professional experience and be given credit for it; and I think the form as given by the Constitution is much preferable to the one given in the amendment.

THE PRESIDENT.—You have heard the amendment proposed by Professor Williams. Those in favor of the amendment will say "aye;" those opposed, "no." The motion is lost.

MR. NORTH.—I would like to suggest an amendment in the first line of Section 4—to change "thirty-three years" to "thirty years."

Motion seconded.

THE PRESIDENT.—It is moved by Mr. North that Section 4 be amended by changing "thirty-three" to "thirty." Those in favor of that motion will signify it by saying "aye;" opposed, "no."

MR. WHINERY.—Mr. President, I do not know that that is a matter of very great importance, but there is in this Society undoubtedly a demand for raising the standard of membership, and I think that is one I can say was to an extent recommended by the Committee as one way that it could very well be done. Thirty years is a comparatively young age for a man to have reached the position in the American Society of Civil Engineers which the Committee, and I think a great many members of our Society, believe, should be represented by the highest grade of membership in the Society; and that matter was given very careful consideration by the Committee, and they were, with the exception that there might be one member who was in the minority report, very strongly in favor of raising the age limit for the highest grade in the Society to thirty-three years.

Mr. HOWARD.—I understand that this Society is not biographical or historical. Is there any good reason why a man who has the industry, integrity and ability to fill the bill should not be admitted at thirty years of age? Would it not have simply the result of discouraging those who are young and ambitious from going into this Society, and entering others where the age qualification is not so high?

MR. SHERRERD.—May I state one question that was considered by the Committee, that is, the age limit? Every Junior must cease to be a Junior, or ceases connection with the Society at the age of thirty-two, and it was thought wise that each Junior should go through the grade of Associate Member before becoming a full Member. This would mean that he would have to get out of the Society and be elected again if he wanted to go from Junior to Member without going through the grade of Associate Member.

Discussion on Amendments (continued).

Motion stated, voted upon and lost.

A MEMBER.—Taking this "honorable standing" in the profession, I would like to know what that is. The way I look at it, there are about half a dozen engineers in the City of New York who could pass on that.

THE CHAIRMAN.—It is rather a reflection upon the gentlemen from New York.

SAME MEMBER.—Not at all. Honorable standing might mean in the sense of whether they are gentlemen. From that point of view, I think the minority report which says a high standing is a better one than that. If you want to take it on the ground that a man's record should be taken from his newspaper notoriety that is one thing. I should like to know what the original Committee meant by the word "honorable."

Mr. WHITE.—I move to amend that by striking out the word "honorable" and substituting the word "high." I think there are more than half a dozen honorable members in New York City. I think all members who have passed the Board of Direction, whether Associate Members, full Members or Juniors, are honorable members.

Motion seconded.

THE PRESIDENT.—It is moved and seconded that the word "high" be substituted for the word "honorable."

MR. WHINERY.—Mr. President, in the report of this same Committee to the Annual Convention, they used language much stronger than that in this report. That was very strongly criticized. They cut it down to the present form as now proposed to meet that criticism. They continued to believe, I think, that they would prefer the statement to be made very much stronger; the word "honorable" is entirely in place there. It conveys the idea, both ideas, if you please, not only of honorable standing in the ordinary sense, but of honorable standing in the profession.

One object of putting that in—of putting in some such clause as that—is to authorize the Board, in considering applications, to take into consideration some other reasons, some other considerations than those formally stated in other parts of the requirements; as members of the Board of Direction and members of the Membership Committee know very well, cases sometimes arise where an applicant seems to comply formally with the requirements as to the time, length of service, character of work, and so on, the requirements of the Constitution; but it is very evident to the Board that, nevertheless, he has not reached a place in the profession which would entitle him to membership in the highest grade in the Society. The Board has always exercised its judgment in that manner, but, strictly speaking, without any authority from the Constitution.

One object in putting such a clause in this language, whether it is made in this particular form or not, is to give the Board that authority to consider something more than formal requirements, and I think that was the position of the Committee and was very fully stated in its report, and I need not go further. As a member of the Committee, I should object to striking out the word "honorable," and I should welcome, and I think I can speak for other members of the Committee and say that they would welcome, the addition of the word "high"—"honorable high standing."

MR. WHITE.—I would accept that, with the consent of the seconder. I do not know who the seconder is.

THE PRESIDENT.—I do not know that Mr. Whinery desired to make the change.

MR. WHITE.—He suggested an amendment to the amendment to make it "honorable high standing."

FOSTER CROWELL, M. AM. SOC. C. E.—I should be in favor of adhering to the word "honorable." "Honorable" is positive and "high" is comparative. It might be quite difficult for the Board of Direction to decide whether a man's position is high. There would not be any difficulty in ascertaining whether it is honorable. I think the one covers the other. It is quite well understood that a man cannot have a very honorable position in the profession unless it is elevated to some degree. It might not necessarily be the highest.

THE PRESIDENT.—The motion to amend as originally made has been modified with the consent of the seconder of the motion so as to provide for the insertion of the word "high" after the word "honorable." Those who are in favor of inserting the word "high" after the word "honorable" in Section 4 will signify by saying "aye;" opposed, "no."

The motion is lost.

MR. WILLIAMS.—I want to try once more for an amendment to this article, and I will go on a line which will meet your approval, I think. I would move to amend the last sentence of Section 4 by inserting after the word "performance" the words "for an equivalent period," and striking out the words "equivalent to active practice," the last of the sentence; and add, "as satisfying the requirements of this section"; so that the sentence will read: "The performance for an equivalent period of the duties of a professor of engineering in any of its branches in such a school shall be considered as satisfying the requirements of this section." Now, that simply does what Professor Swain advocates. It puts the teacher of engineering on a par with his pupils. It does no more, and it does no less. If the section is adopted as it stands, as we interpret it, it would mean that while teaching was considered as equivalent to practice, the candidate could not become a member of

Discussion on Amendments (continued).

this Society until he had had active charge in a position of responsibility, and so forth, of some engineering construction for five years. Now, of course, it may be that that is what the Society desires. I have not thought so, though, up to to-day.

I am not speaking particularly for myself, because I had the opportunity of becoming a Member of this Society before I entered the profession of teaching, and there are very many who have entered the Society since they began teaching; but, as Professor Swain has suggested, many men who are so engaged, and who would be valuable members of this Society, and would contribute as much to its standing as any who are now its members, are prevented and would be prevented, are now prevented and will be in the future prevented, by this section from becoming Corporate Members of this body.

THE PRESIDENT.—You have head the proposed amendment of Mr. Williams, which is seconded.

JAMES BURDEN, M. AM. SOC. C. E.—I would like to ask whether in teaching the profession of engineering, that includes assistants as well as professors. If "professors" does not include "assistants," then it would simply mean that many who had acted in a subordinate position for years would not be admissible as members of the Society although they might have performed more important work than many who as professors were admissible.

MR. WILLIAMS.—To answer that question I would say that, in order to make this section harmonious, we must also amend Section 5, and in amending that section I was going to add the words "professor" or "assistant professor," which would put the assistant professor in the position of Associate Member.

MR. WHINERY.—I would draw attention to the fact that Professor Williams' amendment, if adopted, will admit any professor of any technical school of good standing to the highest grade of membership in the American Society of Civil Engineers. Now, I have always been strongly in favor of admitting professors on similar footing, as practicing engineers, providing their professional standing was equal to it; but I think that very few members here would agree to adopt an amendment which would let in any professor. If any such amendment was undertaken it would require to be carefully thought out and the conditions very carefully defined.

As a matter of fact, this whole question has been considered pretty fully, and a line of action has been decided upon by the Board of Direction of the Society, and that line of action is that, while teaching, honorable as it is, should be considered equivalent to engineering practice, it should not be considered as equivalent to charge of work, to responsible charge of work; and that

the mere fact that a man may be a professor or may have been a professor for a good length of time in a good technical school, ought not to admit him to the highest grade of membership in this Society, unless he has other qualifications prescribed by this Section 5, which would enable him to be admitted.

L. J. JOHNSON, M. AM. SOC. C. E.—I hope that there will be no departure from the use of the words "duties of a professor;" let him have what grade he may. There are certain institutions in this country where the grade of assistant professor is distinguished from that of professor. His duties and responsibilities and prospects in the institution are precisely the same except as they are probably changed by the period of appointment. I hope the term will be retained.

THE PRESIDENT.—The question is on the proposed amendment by Mr. Williams. Those in favor of adopting the amendment of Professor Williams will say "aye;" opposed, "no." The amendment is lost.

The question is now on the adoption of Section 4, which was the original motion. Those in favor of the adoption of Section 4 as reported by the committee will say "aye;" opposed, "no." It is carried.

I will ask those standing in the rear to take seats, or if they wish to converse, to do so outside.

MR. WHINERY.—I now move that Section 5 of Article II, as recommended by the Committee, be adopted and sent out to ballot.

Motion seconded.

THE SECRETARY.—Mr. President, may I say one word about that? The requirement as to the responsible charge of work in each of these sections is identical. The length of time in charge of work is the only difference between the requirements for a Member and for an Associate Member. I believe that that is contrary to the practice which has been in use in the Society and the Board of Direction for a long time. It is recognized that the character of work which will admit a man to the grade of Associate Member is sometimes that on which he would never get in as Member if he were to practice it for twenty years, and I therefore would suggest, although I do not want to make any such motion, that the words "of importance" be left out of that section for Associate Members.

MR. WHINERY.—That matter was very carefully considered by the Committee, and the word "importance" was put in with a distinct purpose. There are so many kinds of engineers, from the construction of a wheel-barrow, or anything of that sort, up to the construction of a bridge, that it seems that the character of work required of experts should be in some way qualified, and this

Discussion on Amendments (continued).

would be the simplest and most practicable way of providing for that.

THE PRESIDENT.—You have heard the motion of Mr. Whinery that Section 5 be adopted and sent out for ballot.

DAVID A. MOLITOR, M. AM. SOC. C. E.—Since the wording of Section 5, the last half of it, is identical with the last half of Section 4, it seems as though Mr. Trautwine's suggestion was in order to cut off the second sentence and simply substitute in its place, "In all other respects, the qualifications to be the same as for member." Mr. Trautwine's suggestion that it is simply in line of brevity to cut out the second sentence, is, I think, correct, and I would make this motion, to cut out the second sentence of Section 5 and substitute in its place, "In all other respects the qualifications to be the same as for members"—the sentence beginning with the words "graduation in a school of engineering," cutting that out, and substituting in the place of it, "In all other respects the qualifications to be the same as for members."

MR. WHINERY.—I see no advantage in it. It is true that we have a repetition there, but repetition is common and it would seem to be unobjectionable where it appears to make the matter clearer. The Committee thought of that and discussed it, and it did not seem wise to try to add some general clause whose only object would be to avoid repetition, and would not accomplish anything. Besides, the particular language now moved would make necessary the modifications and changes in the body of the article, and it seems to me not wise at this time—if the purpose is only to avoid repetition—to adopt that motion.

THE PRESIDENT.—The question is on striking out the latter part of Section 5, beginning with the word "graduation," and ending with the word "practice" at the end of the section, and substituting therefor, "In all other respects the qualifications to be the same as for members." Those in favor of that amendment will say "aye;" opposed, "no." The amendment is lost.

The question is now on the adoption of Section 5, and sending it out to ballot. Those in favor of the adoption of Section 5 will say "aye;" opposed, "no."

MR. NORTH.—In regard to Section 5 it says "Shall have had responsible charge of engineering work of importance for at least one year." I would like to ask Mr. Whinery if that is intended to prevent a man who is, for instance, holding a position, from staying in the Society after he reaches the extreme age of Junior at thirty-two.

THE PRESIDENT.—The vote was in progress, but, if there is no objection, Mr. Whinery will answer the question.

MR. WHINERY.—In answer to that question by Mr. North, I

think that the words "responsible charge" are a very elastic term, but it is necessary and desirable, certainly, that in the qualifications for Associate Members there should be something more than time of service, and I do not think that in view of the past, and the probable coming practice of the Board of Direction of the Society in voting upon the admission of Associate Members, that that would be a test. You cannot make anything that would be absolutely exact.

THE PRESIDENT.—Those in favor of the adoption of Section 5 will say "aye;" opposed, "no." It is adopted.

THE SECRETARY.—Mr. President, the programme which is gotten up with elaborate care by a discriminating committee, states that the luncheon will be served at 1 P. M. It is now half-past one, and we are about one-quarter through with the amendments and I suggest that something be done with the matter, because while we have about one hundred and fifty people here, there are about four hundred who are very hungry downstairs. If this meeting could get through in fifteen minutes it would be all right to remain, but otherwise, I think we had better take a recess.

A MEMBER.—Is there room for the four hundred and for us too?

THE SECRETARY.—Yes, sir.

THE SAME MEMBER.—Then I move we take a recess.

Motion seconded.

THE PRESIDENT.—It is moved and seconded that this meeting take a recess. Those in favor of that motion say "aye;" those opposed, "no."

MR. SHERRERD.—If the mover will withdraw that, I think we can get through with the balance in a very short time because, as I understand, there have been no serious objections to the adoption of the remaining amendments, and they will be adopted and sent out to ballot.

Mr. WILLIAMS.—I would like to call attention to the last sentence of Section 7, although I see no reason why this motion should not be adopted, but I would move that Section 7 be amended by striking out the words "although he may not be a professional engineer."

Motion seconded.

THE PRESIDENT.—It is moved and seconded that the words at the end of Section 7, "Although he may not be a professional engineer," be stricken out. Those in favor of striking out the words "Although he may be a professional engineer," will say "aye;" opposed, "no." The motion is lost.

MR. NORTH.—I would like to make a motion in regard to Section 9. I move that we strike out the words, "A Fellow shall have contributed to the permanent fund of the Society," as not meaning

Discussion on Amendments (continued).

anything at all after July 1st, 1907. The Constitution will be settled, and won't have anything in it that does not mean anything.

Motion seconded.

MR. WHINERY.—I will speak on that very briefly. The grade of Fellow meant in the old days of the Society simply someone who would assist us financially, and I think nothing else. He had no standing, no position in the Society except that, in those days. As we say in the report, we were very thankful for such help, and very thankful to that class of people for helping us. Now, there is no reason why we should accept further additions to that list. Of course, it is understood that this does not abolish the grade entirely. We cannot do that. Those who are now Fellows will remain Fellows as long as they live, but there will be no further addition to the grade. It seems to me that this is entirely a wise procedure, and I hope the Society will see that it is so.

MR. NORTH.—I do not wish to object to the abolition of the grade of Fellow. I merely wish to get out what I thought was redundant in Section 9—the statement of what a Fellow is—as it does not now apply. At the same time, I wish to controvert very directly and very emphatically what has been lately said about a Fellow. I was a Member of this Society when that class was instituted, and a great deal of care was taken in the selection of those who were asked to be Fellows, and persons who were anxious to be Fellows were refused application in two cases that I know of, as not being men who were fit for that position. The Fellows of the Society, when the Fellowship was first established, were men of large reputation, and generally presidents and directors of railroads or else directors of large manufacturing establishments. I take the liberty to differ from Mr. Whinery in this respect, because I think that my knowledge of the history of the Society goes back further than his, and I do not want to have any statement go out to younger members of the Society that the Fellows were not men of almost national reputation.

MR. ALLEN.—I would like to ask what is to become of the present Fellows if this goes through?

THE PRESIDENT.—The question is on the amendment of Mr. North.

MR. BALDWIN.—I think we have no definition of what a Fellow is. It is specified that the membership of the Society shall be Honorary Members, and so forth.

THE PRESIDENT.—Those in favor of the amendment will say "aye;" opposed, "no." The amendment is lost.

The question is on adopting the report of the committee from Section 6 to Section 10, inclusive.

MR. SHERRERD.—And also the amendment of Section 2, Article III.

THE PRESIDENT.—All in favor of adopting those sections of the report of the committee, including the amendment of Section 2, Article III, will say "aye;" opposed, "no."

Motion carried.

THE PRESIDENT.—The work is completed. There is, however, the report of the tellers.

Announcements.

THE SECRETARY.—Before reading the report of the tellers, I should like to announce that owing to the unprecedented demand for tickets to the various excursions and entertainments at the Annual Meeting, we do not know exactly whether we can carry you all on the excursion to-morrow or not, and the only reason that I make this announcement is that the boat which we have chartered, which was the best obtainable, is licensed to carry some thousand or twelve hundred passengers, but unfortunately some of those passengers would have to stay outside.

Now, we have sold over six hundred tickets for that excursion, and there is probably good accommodation for four hundred fifty to five hundred inside. I recommend that some of us at least put on very heavy clothing.

I am also requested to announce tnat no cameras will be allowed in the Milliken Works, and to request all those who have cameras to leave them at home. I think, Mr. President, that there is no use in making announcements of these excursions at the present time.

THE PRESIDENT.—I think you will find a larger audience downstairs.

THE SECRETARY.—I can say that they are already eating downstairs, and the room is very well filled, but provision has been made to feed the faithful up here.

The report of the tellers is as follows:

Report of Tellers.

Report of Tellers Appointed to Canvass the Ballot for the Election of Officers at the Annual Meeting, January 16th, 1907.

Total number of ballots received	825
Defective: Without signature 16; not entitled to vote 1.	17
Ballots counted	808

For President:

George H. Benzenberg	79[illegible]
George B. Francis	7
Charles McMillan	1
V. G. Bogue	1
Charles C. Schneider	1
G. S. Williams	1

Report of Tellers (continued).

Onward Bates	1
Palmer C. Ricketts	1
O. H. Landreth	1

For Vice-Presidents:

John A. Bensel	797
John A. Ockerson	800
W. J. Wilgus	2
Eugene Griffin	1
J. R. Worcester	1
H. W. Hodge	1
J. A. Briggs	1
Charles McMillan	1
George H. Pegram	1
R. Montfort	1
J. F. Hinckley	1
Edgar Marburg	1
J. G. Van Horn	1

For Treasurer:

Joseph M. Knap	808

For Directors, District No. 1:

Allen Hazen	797
George W. Tillson	796
S. S. Wheeler	1
J. F. O'Rourke	1
G. W. Plympton	1
G. E. Gifford	1
Eugene Klapp	1
W. H. McCord	1
C. H. Graham	1
L. L. Tribus	1
Emil Diebitsch	1
E. P. North	1

For Directors, District No. 2:

Frank W. Hodgdon	803

For Directors, District No. 4:

James Christie	798
Dorsey Ash	1
J. A. Atwood	1
H. H. Rousseau	1
F. H. Newell	1
J. S. Deans	1

For Directors, District No. 5:

Horace E. Horton	797
A. Ziesing	1
Ira O. Baker	1
W. M. Hughes	1
A. Gravelle	1

For Directors, District No. 7:

Arthur L. Adams	801
J. H. Dockweiler	1
J. B. Lippincott	1
Clarence T. Johnston	1

WM. COPELAND FURBER,
J. W. DUB. GOULD,
JOSEPH C. WAGNER,
Tellers.

JANUARY 16TH, 1907.

Officers elected.

THE PRESIDENT.—I declare that you have elected as President, George H. Benzenberg; as Vice-Presidents, John A. Bensel and John A. Ockerson; as Treasurer, Joseph M. Knap; and as Directors, Allen Hazen, George W. Tillson, Frank W. Hodgdon, James Christie, Horace E. Horton, and Arthur L. Adams.

In leaving the chair, I wish to thank the Society and the officers of the Society for the uniform courtesies that they have extended to me throughout the year, and for their support. The year has not been a notable one in the sense of having important events included in it, but it has been unparalleled in the growth of the Society in members and in material prosperity, and it also has been a harmonious year. I will ask Mr. Schneider and Mr. Collingwood if they will kindly escort the new President to the platform.

Mr. BENZENBERG.—Mr. President, and gentlemen and members of the American Society of Civil Engineers, I thank you most heartily and sincerely for this expression of your approval and good will, and I trust nothing may happen possibly to convert this into a sigh of relief a year hence. I thank you and all the members of the Society for the distinction and honor which they have this day conferred on me, than which there is no greater in the gift of the American Society of Civil Engineers.

When I look back at the long list of engineers, illustrious men, who have filled so ably this chair, it is with a great many misgivings indeed, and much diffidence, that I assume this seat and the performance of these duties; but with your kind assistance and your kinder forbearance, should I make any mistakes and not

meet your expectations, I will accept the office and perform the duties thereof to the best of my ability.

The hour, gentlemen, is a late one. You have been patient, and have finished up the work. There is a much more attractive feature of the programme awaiting you at the present time. I will, therefore, not take up any further time with an address, even if I could make one that would be of interest. I again thank you for the honor you have conferred upon me to-day, which I appreciate more than I can express. I thank you.

THE SECRETARY.—Mr. President, I would like to announce, in case there may be some members of the Board of Direction present, that just as soon after luncheon as possible there will be a meeting of the Board of Direction held in the Directors' room down stairs, in about an hour from now, and I would also announce that if the gentlemen, when this meeting adjourns, will move to the rear of this room, where the camp chairs are located, they will be looked after more comfortably, and they can be easily served, and the doors will open and the food will begin to pour in.

THE PRESIDENT.—A motion to adjourn this Annual Meeting is now in order.

Adjourned. Motion to adjourn, duly seconded, stated, and carried.

EXCURSIONS AND ENTERTAINMENTS AT THE FIFTY-FOURTH ANNUAL MEETING.

Wednesday, January 16th, 1907.—After the business meeting, luncheon for more than 600 members was served at 1.30 P. M. at the Society House.

At 3 P. M. excursions, under special guidance, were organized, and visited the following engineering works: The new Lackawanna Terminal in Hoboken; the Blackwells Island Bridge; the Fifty-ninth Street Power Station of the Interborough Rapid Transit Company; and the tunnels of the Pennsylvania Railroad crossing Manhattan Island.

At 8 P. M. Eugene Lentilhon, M. Am. Soc. C. E., gave an illustrated lecture on Chili, and at 9 P. M. this was followed by an informal "smoker" which was attended by about 800 members and their guests.

Thursday, January 17th, 1907.—The day was devoted to an excursion by steamer to Staten Island, to visit the new Open-Hearth Steel Plant, Bridge and Structural Shops of Milliken Brothers, Incorporated, by invitation of the owners.

Notwithstanding a severe snow storm and very low temperature, a party of about 500 met at the pier at the foot of West 21st Street at 10 A. M., and embarked on the steamer *Sagamore,* kindly furnished through the courtesy of the Long Island Railroad Company. The steamer, accompanied by the harbor tug *Manhattan,* provided to take those who could not be accommodated on the *Sagamore,* proceeded directly to Milliken, Staten Island, where the steel works are located. Luncheon was served on the boat on the way down the harbor. The party inspected the steel furnaces, gas producers, re-heating furnaces, rolling mills, power-house, machine shop, blacksmith's shop, bridge shop, paint shop, etc. The trip was very enjoyable, although the weather was very severe. Leaving Staten Island at about 3.30 P. M., a landing was made at Pier A at about 5 P. M., after which the steamers proceeded to the West Twenty-first Street pier.

In the evening a party of 385 attended the Hippodrome, and subsequently had supper at the Society House. After supper there was informal dancing until a late hour.

The following list contains the names of 766 members, of various grades, who registered as being in attendance at the Annual Meeting. The list is incomplete, on account of the failure of many members to register, and it does not contain the names of any of the guests of the Society or of individual members. The number of these guests is estimated at 450.

Abbott, E. L....New York City
Abbott, Hunley..New York City
Aiken, W. A.....Pittsburg, Pa.
Aims, Walton I..New York City
Albertson, C....New York City
Alexander, H. J.New York City
Allen, C. Frank..Boston, Mass.
Allen, C. H.....New York City
Allen, Eugene Y.,
South Orange, N. J.
Archer, A. R..Jersey City, N. J.
Arnold, Bion J....Chicago, Ill.
Atkins, H. B..Philadelphia, Pa.
Atkinson, A.,
New Brunswick, N. J.
Auryansen, F..Woodhaven, N. Y.
Averill, F. L.Washington, D. C.

Babcock, W. S..New York City
Backes, W. J...Hartford, Conn.
Bailey, G. I....New York City
Baird, Howard C.,
New York City
Baker, Shirley..New York City
Baldwin, F. H...Brooklyn, N. Y.
Baldwin, W. J...Brooklyn, N. Y.
Ball, L. A.....New York City
Ballinger, W. F.,
Philadelphia, Pa.
Bamford, W. B..New York City
Bance, C. W...Jersey City, N. J.
Bardol, F. V. E..Buffalo, N. Y.
Barker, C. W. T..Aspinwall, Pa.
Barney, P. C...New York City
Barton, C. L....New York City
Bartram, G. C...Brookline, Mass.
Basinger, J. G..New York City
Bates, Onward.....Chicago, Ill.
Baum, George...Yonkers, N. Y.
Beahan, Willard.Cleveland, Ohio
Beekman, J. V. D., Jr.,
Boston, Mass.
Beerbower, G. M.,
New York City
Belden, E. T..New Haven, Conn.
Belknap, F. W..New York City
Belknap, J. M..New York City
Belknap, W. E...New York City
Bellinger, L. F.,
Bath Beach, N. Y.
Belzner, T.....New York City
Bensel, J. A....New York City
Benton, L. S....New York City
Benzenberg, G. H.,
Milwaukee, Wis.
Berger, Bernt...New York City
Berquist, A. S. F.,
Brooklyn, N. Y.
Bettes, C. R.,
Far Rockaway, N. Y.
Betts, F. K....Kingston, N. Y.
Betts, R. T....Brooklyn, N. Y.
Beugler, E. J...New York City
Birks, A. H....Phœnixville, Pa.
Bishop, G. H..Middletown, Conn.
Bissell, C. T...Brooklyn, N. Y.
Bissell, H....W. Medford, Mass.
Blakeley, G. H.,
South Bethlehem, Pa.
Blakeslee, C..New Haven, Conn.
Blanchard, A. H.,
Providence, R. I.
Blatch, Nora S..New York City
Bliss, E. P.....Boston, Mass.
Boardman, H. E.,
New York City
Bogart, John....New York City
Bond, G. W., Jr.,
Weehawken, N. J.
Boniface, Arthur,
New York City
Booth, George W.,
New York City
Booth, W. F.,
Poughkeepsie, N. Y.
Booz, Horace C...Ardmore, Pa.
Boucher, W. J..New York City
Bowman, A. L..New York City
Boyd, James C..Brooklyn, N. Y.
Brace, James H..New York City

Bradley, D. E....Berlin, Conn.
Brady, Joseph...New York City
Brainard, Owen..New York City
Braine, L. F....New York City
Bramwell, G.W..New York City
Braslow, Barnett,
New York City
Bremer, Lewis P.,
New Rochelle, N. Y.
Breuchaud, J. R..Yonkers, N.Y.
Briggs, J. A....New York City
Brinckerhoff, H. W.,
New York City
Brodhead, Calvin E.,
East Mauch Chunk, Pa.
Brown, John G.,
Philadelphia, Pa.
Brown, Le Grand,
Rochester, N. Y.
Brown, M. F.....Boston, Mass.
Brown, Paul G..New York City
Brown, R. C.....Crafton, Pa.
Brown, R. H..Worcester, Mass.
Brown, Thomas E.,
New York City
Brown, W. L...New York City
Brown, W. P...New York City
Bruce, John M..New York City
Brush, W. W..Brooklyn, N. Y.
Bryan, C. W...New York City
Buchholz, C. W..New York City
Buck, H. R....Hartford, Conn.
Buck, L. L.,
Hastings-on-Hudson, N. Y.
Buck, R. S.....New York City
Buffinton, B. T.,
Fall River, Mass.
Bullock, W. D..Providence, R. I.
Burden, James.....Troy, N. Y.
Burdett, F. A...New York City
Burpee, Moses.....Houlton, Me.
Burr, W. H....New York City
Burrowes, H. G..New York City
Bush, E. W....Hartford, Conn.
Bush, H. D.....Baltimore, Md.
Bush, L....East Orange, N. J.
Buzzell, J. W...New York City

Cameron, K. M...New York City
Cantine, E. I.,
East Orange, N. J.
Carlile, T. J....Jamaica, N. Y.
Carpenter, A. W..Yonkers, N. Y.
Carter, A. E...New York City
Carter, F. H..Cambridge, Mass.
Chambers, H. J..New York City
Chambers, R. H..New York City
Chapman, P....Brooklyn, N. Y.
Chappell, T. F..New York City
Chase, R.D..New Bedford, Mass.
Chester, J. N.....Pittsburg, Pa.
Christian, G. L..New York City
Christie, James,
Philadelphia, Pa.
Christy, G. L...New York City
Churchill, C. S...Roanoke, Va.
Clapp, O. F...Providence, R. I.
Clark, G. H....New York City
Clark, W. G.....Tenafly, N. J.
Clarke, E. W...New York City
Clarke, G. C...New York City
Clarke, St. John..Bogota, N. J.
Class, C. Frank..Camden, N. J.
Clermont, J. B..New York City
Codwise, E. B..Kingston, N. Y.
Codwise, H. R..Brooklyn, N. Y.
Coffin, Amory...New York City
Coffin, T. A.,
South Orange, N. J.
Cohen, F. W...Harrisburg, Pa.
Cole, H. O.....Passaic, N. J.
Collier, B. C...New York City
Collingwood, F..Elizabeth, N. J.
Conard, W. R..Burlington, N. J.
Conger, A. A...New York City
Cook, H. A..Jersey City, N. J.
Cook, J. H.....Passaic, N. J.
Coombs, S. E...Yonkers, N. Y.
Cooper, S. L....Yonkers, N. Y.
Corthell, A. B...New York City

Covell, V. R.....Pittsburg, Pa.
Crane, A. S....New York City
Crane, C. A....New York City
Crane, F. E..Amsterdam, N. Y.
Crehore, W. W..New York City
Cresson, B. F., Jr.,
New York City
Crider, J. L..Mt. Vernon, N. Y.
Crooks, C. H...New York City
Crowell, Foster..New York City
Cullen, J. F.,
Havre de Grace, Md.

Dahm, Sverre...New York City
Dailey, J. A..East Orange, N. J.
Dakin, A. H., Jr.,
New York City
Dalrymple, F. W.,
Bayonne, N. J.
Darrow, W. J..New York City
Davis, A. L....New York City
Davis, C. E.,
Brown Station, N. Y.
Davis, Chandler..New York City
Davis, Charles....Pittsburg, Pa.
Davis, J. L.....New York City
Davis, R. B.....Boston, Mass.
Davis, W. R.....Albany, N. Y.
Dawley, E. P..New Haven, Conn.
Dean, A. W....Concord, N. H.
Dean, Luther....Taunton, Mass.
Denio, G. L...Ridgewood, N. J.
Dennis, W. F.,
Washington, D. C.
de Varona, I. M..New York City
Devin, George...New York City
De Witt, P. H.,
Phillipsburg, N. J.
Deyo, S. L. F...New York City
Diamant, A. H..New York City
Diebitsch, E....New York City
Dilks, L. C.....New York City
Dimon, D. Y.....Passaic, N. J.
Dorrance, W. T..New York City
Doty, A. D.....New York City
Doty, J. W.....New York City
Dougherty, R. E.,
New York City
Dow, Alex.....Detroit, Mich.
Dunham, W. R., Jr.,
New Haven, Conn.
Dunlap, F. C...New York City

Earle, F. H., Jr..Newark, N. J.
Easterbrook, F. J.,
New Haven, Conn.
Eddy, H. P...Worcester, Mass.
Edwards, D. G..New York City
Edwards, F.....Troy, N. Y.
Edwards, H. W..New York City
Edwards, J. H....Passaic, N. J.
Edwards, W. R..Baltimore, Md.
Ehrbar, L. H...New York City
Ellis, John W..Woonsocket, R. I.
Ely, John A., Jr..New York City
Ely, John S...Philadelphia, Pa.
Erlandsen, O....New York City
Evans, J. M...Brooklyn, N. Y.
Evans, M. E...New York City

Fairchild, S. E., Jr.,
Philadelphia, Pa.
Farley, J. M.,
White Plains, N. Y.
Farley, P. P...Brooklyn, N. Y.
Farrington, H...Yonkers, N. Y.
Federlein, W. G.New York City
Fenton, L. G...Brooklyn, N. Y.
Ferguson, W. H.,
Philadelphia, Pa.
Fetherston, J. T.,
New Brighton, N. Y.
Fiebeger, G. J.,
West Point, N. Y.
Fisher, E. A...Rochester, N. Y.
Fisher, F. D....New York City
Fisher, H. T...New York City
Fitch, C. L....Brooklyn, N. Y.
FitzRandolph, W. S.,
New York City

Flinn, Alfred D.New York City
Ford, W. H...Philadelphia, Pa.
Foster, E. H...New York City
Foster, T. J...Ridgewood, N. J.
Fougner, H....New York City
Francis, G. B..New York City
Fraser, C. E.,
Richmond Hill, N. Y.
Frazee, J. H...New York City
French, A. H..Brookline, Mass.
French, J. B....Jamaica, N. Y.
Frosell, C. G.....Pencoyd, Pa.
Frost, G. S....Brooklyn, N. Y.
Frye, A. I.....Brooklyn, N. Y.
Fuertes, J. H...New York City
Fuller, F. L.....Boston, Mass.
Fuller, W. B...New York City
Fuller, W. E..Brooklyn, N. Y.
Furber, W. C..Philadelphia, Pa.

Gardiner, F. W..New York City
Garlinghouse, F. L.,
Glenshaw, Pa.
Garrison, F. L..Philadelphia, Pa.
Gartensteig, C..New York City
Gibbs, George...New York City
Giddings, F.....Atchison, Kans.
Gifford, G. E..New York City
Gildersleeve, A. C.,
New York City
Giles, Robert...Lawrence, N. Y.
Gilfillan, G. A....Pittsburg, Pa.
Gillespie, R. H..New York City
Gilman, C..E. Cambridge, Mass.
Goad, C. E.....Toronto, Canada
Goldmark, H...Montreal, Canada
Goldsborough, J. B.,
Croton-on-Hudson, N. Y.
Goodman, J.....New York City
Goodrich, E. P.Brooklyn, N. Y.
Gould, J. W. Du B.,
New York City
Gowen, C. S...Ossining, N. Y.
Gowen, S.....Phœnixville, Pa.
Graham, C. H..New York City
Granbery, J. H..New York City
Grant, T. H...Red Bank, N. J.
Grantham, H. T.,
Philadelphia, Pa.
Gray, J. H.....New York City
Gray, J. L.....Bayonne, N. J.
Green, C. N....New York City
Greene, Carleton,
New York City
Greene, G. S., Jr.,
New York City
Gregory, C. E...New York City
Greiner, J. E....Baltimore, Md.
Grimes, E. L.....Troy, N. Y.
Grimm, C. R..Brooklyn, N. Y.
Guthrie, K. O..Brooklyn, N. Y.

Hager, A. B..Rutherford, N. J.
Hague, C. A...New York City
Haight, S. S...New York City
Haines, C. W...Richmond, Va.
Haines, E. G...Brooklyn, N. Y.
Hale, H. M....New York City
Hale, R. A.....Lawrence, Mass.
Hall, M. W....New York City
Hallock, J. C...New York City
Hallsted, J. C..Montclair, N. J.
Hammond, J.F..Brooklyn, N. Y.
Hanavan, W. L.,
Poughkeepsie, N. Y.
Hansel, C.....New York City
Harby, Isaac.....Trenton, N. J.
Haring, A.....New York City
Harrington, F. F...Norfolk, Va.
Harrington, H. G.,
New York City
Harris, C. M...New York City
Harrison, C. L...New York City
Harrison, E. W.,
Jersey City, N. J.
Harte, C. R..New Haven, Conn.
Harwi, S. J.....New York City
Harwood, G. A.,
White Plains, N. Y.
Haskins, W. J..New York City

Hatton, H. W..Wilmington, Del.
Hauck, W.....Brewster, N. Y.
Hayes, S. W.....Geneva, N. Y.
Hazen, W. N.Mt. Vernon, N. Y.
Heald, E. C..Washington, D. C.
Heindle, W. A..New York City
Heller, J. W...Brooklyn, N. Y.
Hench, N. M.....Pittsburg, Pa.
Henderson, J. T.,
Hartford, Conn.
Henry, P. W...New York City
Herbert, H. M.,
Bound Brook, N. J.
Hering, Rudolph,
New York City
Herrick, J. J.,
Tompkinsville, N. Y.
Herschel, C.....New York City
Hewes, V. H...New York City
Hewett, B. H. M.,
New York City
Hewitt, George..Paterson, N. J.
Higginson, J. Y.,
New London, Conn.
Hillyer, W. R.,
Port Richmond, N. Y.
Hilton, J. C.,
Long Island City, N. Y.
Hoag, S. W., Jr.New York City
Hodgdon, F. W...Boston, Mass.
Hodge, H. W...New York City
Hogan, J. P..High Falls, N. Y.
Hogg, J. B.....Uniontown, Pa.
Hogue, C. J.....Boston, Mass.
Holbrook, Percy.New York City
Holden, C. A...Hanover, N. H.
Hollyday, R. C..New York City
Hone, F. de P..New York City
Honness, G. G...Katonah, N. Y.
Hopper, J. J...New York City
Hopson, E. H...Katonah, N. Y.
Horton, H. E.....Chicago, Ill.
Hough, D. L...New York City
Hovey, O. E...Plainfield, N. J.
How, R. W.....Jamaica, N. Y.
Howard, C. P....Pittsburg, Pa.
Howard, J. L....Melrose, Mass.
Howe, E. W.....Boston, Mass.
Howe, H. N....Brooklyn, N. Y.
Howell, F. S...New York City
Howes, D. W..New Paltz, N. Y.
Howes, R. H...Brookline, Mass.
Hoyt, W. E...Rochester, N. Y.
Hubbell, G. S..Flushing, N. Y.
Hudson, C. W..Phœnixville, Pa.
Hudson, H. W..Woodside, N. Y.
Hughes, H. J..Cambridge, Mass.
Hulse, S. C....New York City
Humphrey, R. L.,
Philadelphia, Pa.
Hunt, C. A....New York City
Hunt, C. E....New York City
Hunt, Charles Warren,
New York City
Hurlbut, C. C.,
White Plains, N. Y.
Hurst, G. J.....New York City
Hyde, W. H.....Bellevue, Pa.

Ilsley, A. B..Washington, D. C.
Irwin, J. C.....New York City
Ives, A. S.....Lynchburg, Va.
Ives, H. C.....Worcester, Mass.

Jacobs, C. M...New York City
Jacobs, R. H...New York City
Jacoby, H. S.....Ithaca, N. Y.
Janvrin, N. H..New York City
Japp, Henry,
Richmond Hill, N. Y.
Jarrett, E. S...New York City
Jenkins, J. E...New York City
Johnson, A.....New York City
Johnson, L. J..Cambridge, Mass.
Johnstone, W. B,
New York City
Jonson, Ernst F..New York City
Jordan, E. C.....Portland, Me.
Jouett, H. D...New York City

Just, G. A.,
Long Island City, N. Y.

Kaufman, G....New York City
Keays, R. H...New York City
Keith, H. C.....New York City
Keller, O. B....New York City
Kelley, W. D...Yonkers, N. Y.
Kenney, E. F.....Moore, Pa.
Ketchum, M....New York City
Khuen, Richard...Pittsburg, Pa.
Kimball, G. A....Boston, Mass.
King, W., Jr...New York City
Kinnear, W. S...Detroit, Mich.
Kinsley, T. P..New York City
Kittredge, G. W..Yonkers, N. Y.
Klapp, Eugene..New York City
Knap, E. D....Brooklyn, N. Y.
Knap, J. M....New York City
Knickerbacker, J...Troy, N. Y.
Knight, F. B..Brooklyn, N. Y.
Knighton, J. A.New York City
Knowles, M....Pittsburg, Mass.
Kolb, H. J.....Brooklyn, N. Y.
Kreuger, I.....New York City
Kuichling, E....New York City
Kummer, F. A..New York City

Langthorn, J. S..Kingston, N. Y.
Lannan, L. E.....Corry, Pa.
Larmon, F. P..Waterford, N. Y.
Larsson, C. G. E.,
Plainfield, N. J.
Lavis, F.....Mt. Vernon, N. Y.
Leather, B. H..New York City
Lee, E. M.....Paterson, N. J.
Lee, W. B.....Hillburn, N. Y.
Leeuw, H.....Arlington, N. J.
Leffingwell, F. D.,
Montclair, N. J.
Leffler, B. R....Cleveland, Ohio
Leighton, G.....Glenburn, Pa.
Leland, G. H..Providence, R. I.
Lentilhon, E..Bay Shore, N. Y.
Lepper, F. W...Cleveland, Ohio
Lesley, R. W..Philadelphia, Pa.
Letson, T. H...New York City
Lewinson, M...Scarsdale, N. Y.
Lewis, E. W..New Haven, Conn.
Lewis, L. H...New York City
Lewis, N. P....Brooklyn, N. Y.
Lewis, R. T.....Elmira, N. Y.
Lex, W. I.....Philadelphia, Pa.
Libbey, J. T.....Corry, Pa.
Lieb, J. W., Jr...New York City
Linnell, H. P..Worcester, Mass.
Lippincott, J. B.,
Los Angeles, Cal.
Llewellyn, F. T..New York City
Lobo, Carlos....Brooklyn, N. Y.
Lockwood, J. A..New York City
Lofland, H. F..Philadelphia, Pa.
Logan, W. S...Arlington, N. J.
Long, E. McL..New York City
Look, M. J.....Katonah, N. Y.
Lovell, E. B...New York City
Low, George E..New York City
Lowinson, O....New York City
Lucas, G. L....New York City
Lund, G. A....New York City

MacCracken, G. G.,
New York City
Macdonald, H. P.,
Montclair, N. J.
MacGregor, R. A.,
New York City
Machen, H. B..New York City
Macnab, G. T..New York City
MacNeille, P. R.,
New York City
McClave, S. W., Jr.,
Grantwood, N. J.
McClintock, J. R.,
New York City
McComb, D. E.,
Washington, D. C.
McHarg, Leslie..New York City
McKenna, C. F..New York City

McKenzie, T. H.,
Southington, Conn.
McMinn, T. J..Brooklyn, N. Y.
McNulty, G. W.New York City
Madden, J. H..New York City
Malukoff, A. J..New York City
Marburg, Edgar,
Philadelphia, Pa.
Marple, W. M....Scranton, Pa.
Martin, Wisner..Maywood, N. J.
Mason, Francis..New York City
Matheson, E. G.,
East Orange, N. J.
Matheson, J. D..New York City
Matlaw, I. S.....Troy, N. Y.
Mead, C. A.,
Upper Montclair, N. J.
Mebus, C. F..Philadelphia, Pa.
Merriman T.,
West Shokan, N. Y.
Merryman, W. C.,
New York City
Metcalf, L.....Boston, Mass.
Meyer, H. C...New York City
Meyers, C. W..New York City
Miller, Frank ....Passaic, N. J.
Miller, R. P...New York City
Mills, C. M...Philadelphia, Pa.
Minor, E. E..New Haven, Conn.
Mitchell, S. P..Philadelphia, Pa.
Modjeski, Ralph ...Chicago, Ill.
Molitor, David A.,
Washington, D. C.
Moncure, W. A.,
Philadelphia, Pa.
Montfort, R.....Louisville, Ky.
Moore, W. H..New Haven, Conn.
Morse, C. A.....Topeka, Kans.
Morse, C. M.....Buffalo, N. Y.
Morton, W. S..Hartford, Conn.
Moss, R. E.....New York City
Mould, G. A. H..New York City
Moulton, Mace..New York City
Musson, E. F...Norwich, N. Y.
Myers, John H.,
White Plains, N. Y.

Neely, W. R.....Albany, N. Y.
Neumeyer, R. E..Bethlehem, Pa.
Nial, W. A....New York City
Nichol, H. S...New York City
Nichols, C. H.,
New Haven, Conn.
Nichols, O. F..Brooklyn, N. Y.
Nimmo, J. V..Paspebiac, Canada
Noble, Alfred...New York City
Noble, F. C....Brooklyn, N. Y.
North, E. P....New York City
Nostrand, P. E..Brooklyn, N. Y.
Nye, A. S..Kingsbridge, N. Y.

O'Brien, J. H...New York City
Odell, F. S..Port Chester, N. Y.
Oestreich, H. L..New York City
Ogden, H. N.....Ithaca, N. Y.
Opdyke, S. B., Jr.,
New York City
O'Rourke, J. F..New York City
Orr, A. .....Gloversville, N. Y.
Orrok, G. A....Flatbush, N. Y.
Osgood, J. O..Jersey City, N. J.
Otagawa, M.....Tokio, Japan
Owen, E. H....New York City
Owen, James ...Newark, N. J.
Owen, K. D...Montclair, N. J.
Oxholm, T. S.,
West Brighton, N. Y.

Park, J. C.....Cranford, N. J.
Parker, A. McC.New York City
Parker, C. J...New York City
Parker, J. C...Rochester, N. Y.
Parker, W.....Boston, Mass.
Parsons, G. W....Steelton, Pa.
Parsons, H. C...Albany, N. Y.
Parsons, H. de B.,
New York City
Parsons, W. B..New York City
Paschke, T.....New York City
Pegram, G. H..New York City
Pemoff, J. J...New York City
Pendlebury, E....Newark, N. J.
Perkins, C. E..Columbus, Ohio

Perry, J. P. H...New York City
Peterson, J.....New York City
Pike, R. A..Mt. Vernon, N. Y.
Piper, A. R....Brooklyn, N. Y.
Pistor, G. E. J.,
East Orange, N. J.
Plympton, G. W.,
Brooklyn, N. Y.
Polk, W. A....New York City
Pollock, C. D..Brooklyn, N. Y.
Porter, H. T....Greenville, Pa.
Porter, J. E....Yonkers, N. Y.
Post, H. W.,
Richmond Hill, N. Y.
Powers, C. V. V.New York City
Pratt, W. A..New Rochelle, N. Y.
Preston, H. W...Elmira, N. Y.
Price, P. W.....Oakmont, Pa.
Priest, B. B..East Orange, N. J.
Prince, A. D...New York City
Proctor, R. F...New York City
Pruyn, F. L....New York City

Quincy, C. F...New York City
Quirk, E. McG.,
Montreal, Canada

Rainbow, J. R..New York City
Ray, D. H.....New York City
Read, R. L.....Malden, Mass.
Reed, W. B....New York City
Reichmann, A. F....Chicago, Ill.
Reynders, J. V. W..Steelton, Pa.
Reynolds, J. O..Brooklyn, N. Y.
Reynolds, L. C.,
Mt. Vernon, N. Y.
Rhodes, F. D..Jersey City, N. J.
Rice, G. S.....New York City
Richardson, J. H..Orange, N. J.
Ridgway, R..Poughkeepsie, N. Y.
Riedel, J. C...Brooklyn, N. Y.
Riegler, L. J....Ben Avon, Pa.
Riegner, W. B..Philadelphia, Pa.
Riggs, M. J.....Toledo, Ohio
Rights, L. D....New York City
Robbins, A. A..New York City
Roberts, W.....Waltham, Mass.
Rogers, H. L...New York City
Ropes, H.....Englewood, N. J.
Rose, R. V..Niagara Falls, N. Y.
Ross, E. W....Providence, R. I.
Rowell, G. F...New York City
Rowland, C. B..New York City
Ryan, M. H...New York City
Ryder, E. M. T.,
New Haven, Conn.

Sabin, A. H...Flushing, N. Y.
Sabine, E. D...New York City
Sanborn, F. B..Cambridge, Mass.
Sanborn, J. F.,
Poughkeepsie, N. Y.
Sanford, G. O..Buford, N. Dak.
Sapp, E. H....Wenonah, N. J.
Saunders, G. C.,
Philadelphia, Pa.
Saunders, W. L..Plainfield, N. J.
Sayers, E. L...New York City
Sayles, R. W...New York City
Schaeffer, A....New York City
Schermerhorn, R., Jr.,
Brooklyn, N. Y.
Schmidt, M. E.,
Morristown, N. J.
Schneider, A....New York City
Schneider, C. C.,
Philadelphia, Pa.
Schoder, E. W...Ithaca, N. Y.
Schofield, H. A.,
Philadelphia, Pa.
Scholtz, H. F...Louisville, Ky.
Schumann, C. J.,
Brooklyn, N. Y.
Schwiers, F. W..New York City
Seaman, H. B..New York City
Searle, C. D....New York City
Sears, W. H....New York City
Selby, O. E....Cincinnati, Ohio
Sergeant, G., Jr..New York City
Shedd, G. G...Fall River, Mass.

Shellenberger, L. R.,
New York City
Shepherd, F. C..New York City
Sherrerd, M. R..Newark, N. J.
Shiebler, M.....New York City
Shoemaker, M. N..Newark, N.J.
Simpson, G. F..New York City
Sinclair, F. O..Burlington, Vt.
Sitt, W. T.....New York City
Skinner, F. W.,
Tompkinsville, N. Y.
Skinner, J. F..Rochester, N. Y.
Sleeper, G. E....Newark, N. J.
Slocum, C.L..New Haven, Conn.
Smith, A.....New York City
Smith, C. E....Ossining, N. Y.
Smith, E. M.....Chicago, Ill.
Smith, J. W...New York City
Smith, L. C. L.,
Long Island City, N. Y.
Smith, M. H.,
White Plains, N. Y.
Smith, Oberlin..Bridgeton, N. J.
Smith, W. F...New York City
Snare, F.....New York City
Snell, H. B....Brooklyn, N. Y.
Snow, C. H....New York City
Snow, J. P.....Boston, Mass.
Snyder, G. D...New York City
Soper, G. A....New York City
Spear, P. H.....Ludlow, N. Y.
Spencer, W. T.,
New Haven, Conn.
Sperry, H. M..New York City
Spofford, C. M..Brooklyn, N. Y.
Spooner, A. N..New York City
Sprague, E. L., Jr.,
Valhalla, N. Y.
Staats, J. H.....New York City
Staniford, C. W..Brooklyn, N.Y.
Stanton, R. B..New York City
Stearns, F. L...New York City
Stearns, F. P.....Boston, Mass.
Steegmuller, C. A. A.,
Jersey City, N. J.
Stern, E. W....New York City
Stevenson, W. F..New York City
Stiger, J. S., Jr.,
Bernardsville, N. J.
Stoddard, G. C.New York City
Strickler, G. B.,
Washington, D. C.
Strobel, C. L.....Chicago, Ill.
Strong, J. B....Hillburn, N. J.
Strong, M. R....Passaic, N. J.
Strouse, W. F...Baltimore, Md.
Stuart, A. A...Brooklyn, N. Y.
Stuart, J. T...Philadelphia, Pa.
Sullivan, J. G.,
Culebra, Canal Zone
Suter, R.....New York City
Sutermeister, A. H.,
Albany, N. Y.
Swensson, E.....Pittsburg, Pa.
Swezey, E. C...Brooklyn, N. Y.
Swift, W. E.,
Cornwall-on-Hudson, N. Y.
Swindells, J. S..New York City
Sykes, G.....New York City

Taber, G. A...Brooklyn, N. Y.
Taft, J. R.....New York City
Tait, J. G....Waterford, N. Y.
Tallman, P. B.,
East Orange, N. J.
Tarr, C. W.....Babylon, N. Y.
Taylor, A. J...Wilmington, Del.
Taylor, L. A..Worcester, Mass.
Taylor, S. A.....Pittsburg, Pa.
Thacher, E.....Flushing, N. Y.
Theban, J. G...New York City
Thomas, G. E...New York City
Thomes, E. H...Jamaica, N. Y.
Thompson, S. C..New York City
Thompson, S. E.,
Newton Highlands, Mass.
Thomson, G. H..New York City
Thomson, John..New York City
Thomson, S. F..New Paltz, N.Y.
Thomson, T. K..New York City

Thornley, J.....New York City
Tibbals, S. G..Brooklyn, N. Y.
Tidd, A. W..White Plains, N. Y.
Tighe, J. L.....Holyoke, Mass.
Tillson, G. W..Brooklyn, N. Y.
Tingley, R. H..New York City
Tompkins, E. De V.,
New York City
Tonkin Thomas, J.,
Santiago, Chile
Tooker, F. W...New York City
Tozzer, A. C...New York City
Trautwine, J. C., Jr.,
Philadelphia, Pa.
Travell, W. B..Plainfield, N. J.
Tretter, G. A..Phœnixville, Pa.
Tribus, L. L....New York City
Triest, W. G...New York City
Trout, C. E....New York City
Trow, F. H.....Clinton, Mass.
Tucker, L. W..New York City
Tucker, W. C..New York City
Tull, R. W.....New York City
Turner, E. K.....Boston, Mass.
Tuttle, A. S...New York City

Ulrich, D.....Katonah, N. Y.
Upjohn, H. B..New York City

Vail, J. J.....Rahway, N. J.
Value, B. R..McCall Ferry, Pa.
Van Horne, J. G..New York City
Van Norden, E. M.,
Brooklyn, N. Y.
Vaughan, C. H.,
New Brighton, N. Y.
Verveer, E. L..New York City
Vier, H.....New York City
Vogleson, J. A..New York City
von Leer, I. W..Philadelphia, Pa.
Voorhees, Paul..Harrisburg, Pa.
Vorce, C. B....New York City
Vredenburgh, W., Jr.,
New York City
Vrooman, M..Gloversville, N. Y.

Wachter, C. L..Hoboken, N. J.
Waddell, F. C...New York City
Wadsworth, G. R.,
New York City
Wadsworth, J. E.,
New York City
Wagner, J. C..Philadelphia, Pa.
Wagner, S. T...Philadelphia, Pa.
Waite, D. C....Yonkers, N. Y.
Waite, G. B.,
Whitestone, L. I., N. Y.
Waitt, A. M...New York City
Waldron, S. P..New York City
Walker, J. J..Dobbs Ferry, N. Y.
Walker, J. W....Pittsburg, Pa.
Ward, C. D....New York City
Waterhouse, J..New York City
Watkins, F. W.,
White Plains, N. Y.
Webster, A. L..New York City
Webster, G. S..Philadelphia, Pa.
Webster, W. R..Philadelphia, Pa.
Wegmann, E....New York City
Wells, J. A....New York City
Wendt, E. F.....Pittsburg, Pa.
West, O. J.....Chicago, Ill.
Weston, R. S.....Boston, Mass.
Wheeler, S. S....Ampere, N. J.
Whinery, S...East Orange, N. J.
Whipple, G. C..New York City
Whiskeman, J. P.,
New York City
Whistler, T. D..New York City
White, T. S...Beaver Falls, Pa.
White, W. M...New York City
Whitney, F. O....Boston, Mass.
Whitson, A. U..Eastport, N. Y.
Whittemore, W. F.,
Hoboken, N. J.
Wiggin, T. H..Brooklyn, N. Y.
Wilcock, F.....Brooklyn, N. Y.
Wild, H. J...Weehawken, N. J.
Wilkes, J. K.,
New Rochelle, N. Y.

Wilkins, G. S..New York City
Wilkins, W. G...Pittsburg, Pa.
Williams, G. S.,
Ann Arbor, Mich.
Wills, A. J....Philadelphia, Pa.
Wilson, C. A..Cincinnati, Ohio
Wilson, C. W. S.,
New Rochelle, N. Y.
Wilson, H. M.,
Washington, D. C.
Winsor, F. E.,
White Plains, N. Y.
Wolverton, I. M.,
Mt. Vernon, Ohio.
Wood, F. J.....Foxboro, Mass.
Wood, G. R.....Pittsburg, Pa.
Wood, H. B.....Boston, Mass.
Woodard, S. H...New York City
Wortendyke, N. D.,
Jersey City, N. J.
Worthington, C..New York City
Wyman, A. M..E. Orange, N. J.

Yates, E. A....New York City
Yates, J. J.....Elizabeth, N. J.
Yates, P. K....New York City
Yates, W. H....New York City
Young, C. G...New York City

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, March 6th, 1907.—8.30 P. M.—A regular business meeting will be held. Ballots for membership and on the proposed amendments to the Constitution will be canvassed, and a paper entitled "Uniformity of Requirement and Clearness of Specification in Agreements for the Graduation of Railroads," by W. F. Dennis, M. Am. Soc. C. E., will be presented for discussion.

This paper was printed in *Proceedings* for January, 1907.

Wednesday, March 20th, 1907.—8.30 P. M.—At this meeting a paper entitled "The Lower Colorado River and the Salton Basin," by C. E. Grunsky, M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings.*

Wednesday, April 3d, 1907.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper entitled "Movable Bridges," by C. C. Schneider, Past-President, Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings.*

ANNUAL CONVENTION.

The Thirty-ninth Annual Convention of the Society will be held in the City of Mexico, but the precise date has not yet been fixed; it will be held, however, between June 20th and July 20th, 1907.

The decision of the Board, to hold the Convention in the City of Mexico, is mainly due to a special invitation received from President Diaz, through his Minister of Public Works, Mr. Leandro Fernandez, who is also President of the Mexican Society of Engineers; it is also due to the fact that either free, or practically free, transportation has been promised from the United States border, not only to the City of Mexico, but also for such excursions as may be decided upon.

A committee of the Board, consisting of Messrs. A. L. Bowman, J. Waldo Smith, and the Secretary, has been appointed to take charge of all arrangements on behalf of the Board, and, as soon as the time is fixed definitely and other preliminaries are arranged, a circular will be issued for the information of the membership.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all meetings:

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Society of Engineers, 17 Victoria Street, Westminster, S. W., England.

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston Mass.

Civil Engineers' Club of Cleveland, 718 Caxton Building, Cleveland, Ohio.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa.

Engineers' Society of Western Pennsylvania, 803 Fulton Building, Pittsburg, Pa.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

Louisiana Engineering Society, 604 Tulane-Newcomb Building, New Orleans, La.

Engineers' Club of Central Pennsylvania, Corner Second and Walnut Streets, Harrisburg, Pa.

Engineers' and Architects' Club of Louisville, Ky., 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

Teknisk Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Société des Ingénieurs Civils de France, 19 Rue Blanche, Paris, France.

Svenska Teknologförenigen, Brunkebergstorg 18, Stockholm, Sweden.

Institute of Marine Engineers, 58 Romford Road, Stratford, London, E., England.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Pacific Northwest Society of Engineers, 617–618 Pioneer Building, Seattle, Wash.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Memphis Engineering Society, Memphis, Tenn.

Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

The Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Institution of Engineers of the River Plate, Buenos Aires, Argentine Republic.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Cleveland Institute of Engineers, Middlesbrough, England.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Rochester Engineering Society, Rochester, N. Y.

SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

In reference to this work, a summary of all searches made to date will be found in the Appendix* to the Annual Report of the Board of Direction for the year ending December 31st, 1906.

* *Proceedings*, Vol. XXXIII, p. 20 (January, 1907).

ACCESSIONS TO THE LIBRARY.

From January 8th to February 11th, 1907.

DONATIONS.*

CONCRETE AND REINFORCED CONCRETE CONSTRUCTION.

By Homer A. Reid, Assoc. M. Am. Soc. C. E. Cloth, 9 x 6 in., illus., 18 + 884 pp. New York, The Myron C. Clark Publishing Co., 1907. $5 net. (Donated by the Author.)

It has been the author's aim in the preparation of this book to make it, as far as possible within reasonable limits, a complete treatise on the properties and uses of concrete and reinforced concrete, as applied to construction, and to present a logical development of the subject. It is not only intended as a reference work for engineers, architects and contractors, but, it is believed, the treatment is sufficiently simple for the engineering student and the general reader. The Contents are: Classification and Manufacture of Cement; Properties of Cement and Methods of Testing; Sand, Broken Stone and Gravel; Proportioning Concrete; Mixing Concrete; Placing Concrete; Cost of Concrete; Finishing Concrete Surfaces; General Physical Properties; The General Elastic Properties of Concrete; Physical Properties of Reinforcing Metals; Principles and Disposition of Reinforcement; Mechanical Bond; Styles of Slab Reinforcement; Styles of Beam Reinforcement; Curved Pieces Strained in Flexure; Columns, Walls and Pipes; General Phenomena of Flexure; Theory of Beams; Various Beam Theories; Theory of Columns; Foundations; General Building Construction; Practical Construction; Retaining Walls; Dams; Conduits and Sewers; Tank and Reservoir Construction; Chimneys, Tunnels, Subways, Railroad Ties, Fence Posts, Piers and Wharves; Concrete in Bridge Construction; Arch Bridge Centers and Methods of Construction; Bridge Floors; Bridges, Piers and Abutments; Concrete Building Blocks. There is an index of ten pages.

GAS AND OIL ENGINES.

By Horace Allen. Cloth, 9 x 6 in., illus., 7 + 548 + 6 pp. Manchester, England, Scientific Publishing Company. 12 shillings 6 pence net.

Many points which enter into gas engine practice, and which, it seems to the author, have not previously received the attention they deserve, have been, it is stated, presented in this book. A number of special tables and diagrams have also been prepared for draftsmen and others interested in the design and application of internal-combustion engines to industrial purposes. The arrangement of the book passes, in the earlier chapters, through a consideration of the various principles and details to a general description of types by various makers, which, it is thought, will be found fairly typical of current practice. Two-cycle engines, as well as the question of scavenging and compounding, are discussed in separate chapters. Two chapters are devoted to the description and analysis of engines in which oil and petrol are used as fuel. A brief description is given of the considerable improvements, embodied in later practice, in pressure gas producers. Some information on the suction-gas producer is included, and the application of blast-furnace gas is treated in a special chapter. In the practical working of engines, the question of cost of power, testing and lubricating is considered. There is an index of more than five pages.

ALTERNATING CURRENT MOTORS.

By A. S. McAllister. Cloth, 9 x 6 in., illus., 9 + 278 pp. New York, McGraw Publishing Company, 1906. $3 net.

The electromagnetic phenomena of alternating-current motors have been dealt with, it is stated, in the simplest possible manner, in so far as is consistent with accuracy. Wherever mathematical equations are used, the assumptions upon which they are based are definitely stated, and the inaccuracies in the assumptions and the limitations in the equations are carefully noted. The results obtained from the transformed equations are interpreted with due regard to these inaccuracies and limitations. Moreover, the significance of each transformation is carefully explained, so that the reader may be constantly reminded

* Unless otherwise specified, books in this list have been donated by the publisher.

of the fact that he is dealing directly with electromagnetic phenomena and only indirectly with mathematics. It is assumed that the reader is familiar with the fundamental facts of electricity and magnetism and the lower branches of mathematics, and therefore no attempt is made to explain the manner in which alternating electromotive forces and currents may be represented in value and time-phase position by straight lines. Much attention is given to graphical diagrams and to the examination of facts upon which they are based. There is an index of six pages.

THE COST OF LOCOMOTIVE OPERATION.

By George R. Henderson. Cloth, 9 x 6 in., illus., 195 pp. New York, The Railroad Gazette, 1906. $2.50.

It is hoped that a clear understanding of the Cost of Locomotive Operation may be had from this study, together with the effects, upon it, of physical influences. It is, of course, out of the question to determine or present absolute figures of cost which can be used without qualification, as prices of material and labor vary throughout the country, and are also subject to continual fluctuations. An attempt, however, is made to determine the effects of different circumstances upon the cost of producing transportation and the methods of reducing this to the lowest limit; in most cases, the variation of costs can also be found in the form of a ratio, so that, knowing the unit or base, the cost may be closely estimated. It is stated, therefore, that these investigations may properly cover the following: (1) The cost and value of materials, with the expense of handling and caring for them. (2) The returns obtained by methods of using the different supplies. (3) The effect of grade, speed, loading, etc., upon the consumption of both material and labor. (4) The combined effects upon all items which go to make up locomotive operating expenses. There is an index of three pages.

ELECTRICAL ENGINEERING.

An Elementary Text-Book Suitable for Persons Employed in the Mechanical and Electrical Engineering Trades, for Elementary Students of Electrical Engineering, and for All Who Wish to Acquire a Knowledge of the Chief Principles and Practice of the Subject. By E. Rosenberg. Translated by W. W. Haldane Gee and Carl Kinzbrunner. Authorized Edition, Revised and Brought Down to Date for the American Market by Edward B. Raymond. Cloth, 9 x 6 in., illus., 13 + 347 pp. New York, John Wiley & Sons, 1907. $2.00 net.

The origin of this book was a series of lectures delivered by the author before the workmen and staff of an electrical manufacturing firm. In addition to the phenomena of the electric current, it includes descriptions and explanations of the workings of the most important types of dynamos and motors for continuous, alternating and three-phase current accumulators and their apparatus; measuring instruments; and electric lighting. It is stated in the translator's preface that the explanations of the principles of alternating currents and polyphase work have been made especially clear. For this translation, the illustrations have been revised and added to, and subjects essential to American and English practice are also included. The Contents are: Fundamental Principles; Magnets —Magnetic Lines of Force; The Continuous-Current Dynamo; The Electric Motor; Accumulators; Working of Direct-Current Dynamos in Parallel; Electric Lighting; Alternating Currents; Alternators; Alternating-Current Motors; Multiphase Alternating Current; High Tension. There is an index of nine pages.

REINFORCED CONCRETE.

By Charles F. Marsh, M. Am. Soc. C. E. and William Dunn. Third edition, Revised and Enlarged. Cloth, 11 x 8 in., illus., 7 + 654 pp. London, Archibald Constable & Co., Ltd., 1906. $7 net. (Donated by the Author).

The preface states, that since the publication of the first edition of this work, in 1904, such progress has been made in the study and use of reinforced concrete, as to render necessary a careful revision and considerable enlargement. That portion of the book dealing with calculations has been completely rewritten and simplified, while considerable new matter has been added, including methods for

obtaining the loads on Bins and Silos and the resistance of circular and annular sections to flexure. The method of treatment for singly reinforced rectangular and T-beams is entirely new, and the diagrams for these pieces reduce the work necessary for the calculation of their dimensions to a minimum. The sections on arches and the calculation of pieces under direct compression and flexure combined have been completely rewritten, and practical working examples have been given for finding the curve of pressures on the various types of arches. Several appendices have been added, including some tests, made by Mr. Quinton of the American Geological Survey Department, on the resistance of large pipes to water pressure; and the Prussian Government Regulations. There is an alphabetical index of sixteen pages.

Gifts have also been received from the following:

Am. Inst. of Min. Engrs. 1 pam.
Am. Mathematical Soc. 1 pam.
Cal.-Dept. of Highways. 1 pam.
Cambridge, Mass.-Water Board. 1 pam.
Canada-Dept. of Rys. and Canals. 1 vol.
Cape of Good Hope-Govt. Stationery Office. 1 pam.
Carnegie Inst. of Washington. 1 vol.
Colo.-Agri. Exper. Station. 2 pam.
Conn.-State R. R. Commrs. 1 bound vol.
Cornell Univ. 1 pam.
Cunningham, A. C. 1 pam.
Eastern Bengal and Assam-Public Works Dept. 1 pam.
Eng. Standards Comm. 2 pam.
Farley, G. P. 3 pam., 1 bound vol.
Fendall, B. T. 1 pam.
Fisk and Robinson. 1 pam.
Fuller, F. L. 20 pam.
Great Britain-Patent Office. 11 vol., 4 pam.
Haupt, L. M. 1 pam.
Hunt, L. E. 1 pam.
Illinois-State Geol. Survey. 1 bound vol.
Illinois Univ.-Agri. Exper. Station. 1 pam.
Kernot, W. C. 1 bound vol.
Maine-State Board of Health. 2 bound vol.
Mass.-State Board of Harbor and Land Commrs. 1 bound vol.
Mass. Inst. of Tech. 1 pam.
Merchants' Assoc. of New York. 1 pam.
Met. Ry. Co. 1 pam.
Michel, Henry. 1 pam.
Minnesota-R. R. and Warehouse Comm. 1 bound vol.
Municipal Art Soc. of New York. 1 bound vol.
Nash, Geo., & Co. 1 pam.
New South Wales-Govt. Statistician. 1 pam.
New York City-Board of Rapid Transit R. R. Commrs. 1 vol.
New York City-Comptroller. 1 bound vol.
New York City-Dept. of Parks. 1 vol.
New York City-Dept. of Water Supply, Gas and Electricity. 2 vol.
New York City Record. 2 bound vol.
New York Univ. 1 vol.
North, E. P. 5 vol., 1 pam.
Ohio-State Board of Health. 1 bound vol.
Philadelphia, Pa.-Mayor. 3 bound vol.
Platt, T. C. 3 pam.
Playá, José. 1 pam.
Ry. Signal Assoc. 1 pam.
Royal Military Coll. Club of Canada. 1 vol.
Rugby Eng. Soc. 1 bound vol.
St. Louis, Mo.-Board of Public Impvts. 9 bound vol.
Schussler, Hermann. 1 vol.
Scientific Publishing Co. 1 bound vol.
Sherrerd, M. R. 1 vol.
Shonts, T. P. 2 pam.
South Eastern Ry. Co. 2 pam.
U. S. Bureau of Insular Affairs. 1 vol.
U. S. Bureau of Steam Eng. 1 pam.
U. S. Coast and Geodetic Survey. 2 pam.
U. S. Corps of Engrs. 14 specifications.
U. S. Dept. of Agriculture. 1 vol.
U. S. Forest Service. 3 pam.
U. S. Geol. Survey. 5 vol., 5 pam.
U. S. Interstate Commerce Comm. 5 pam.
U. S. Isthmian Canal Comm. 1 pam.
U. S. Naval Observatory. 1 pam.
U. S. War Dept. 2 pam.
U. S. Weather Bureau. 1 bound vol.
Vernon-Harcourt, L. F. 1 pam.
Worcester Polytechnic Inst. 1 vol.

BY PURCHASE.

Die Assanierung von Cöln. Herausgegeben von Th. Weyl. Leipzig, Wilhelm Engelmann, 1906.

Portland Cement; its Composition, Raw Materials, Manufacture, Testing and Analysis. By Richard K. Meade. Easton, The Chemical Publishing Company, 1906.

Boiler-Waters; Scale, Corrosion, Foaming. By William Wallace Christie. New York, D. Van Nostrand Company, 1906.

Nitro-Explosives; a Practical Treatise Concerning the Properties, Manufacture and Analysis of Nitrated Substances, Including the Fulminates, Smokeless Powders and Celluloid. By P. Gerald Sanford, New York, D. Van Nostrand Company; London, Crosby Lockwood and Son, 1906.

A Bibliography of Municipal Problems and City Conditions. By Robert C. Brooks. Second Edition, Revised and Enlarged. New York Reform Club, Committee on City Affairs, 1901.

Mitteilungen der Materialprüfungs-Anstalt am Schweiz. Polytechnikum in Zürich. Von L. Tetmajer. Heft I–II, VIII–IX. Zürich, F. Lohbauer, 1896–1901.

SUMMARY OF ACCESSIONS.

From January 8th to February 11th, 1907.

Donations (including 14 duplicates)	161
By purchase	7
Total	168

MEMBERSHIP.

ADDITIONS.

MEMBERS.		Date of Membership.
ANDERSON, JOSHUA THOMAS NOBLE. Queens Coll., Belfast, Ireland		Nov. 7, 1906
BENNETT, SAMUEL GIVENS. 228 So. Ave. 66, Los Angeles, Cal		Oct. 3, 1906
BENTZON, ADRIAN BENONI. Civ. Engr. and Contr., Calle San Marcelo 320 altos, Lima, Peru	Assoc. M. M.	Mar. 6, 1901 Sept. 4, 1906
CANNON, MADISON MOTT. Civ. Engr., Fore River Shipbuilding Co., Brunswick, Ga		Jan. 2, 1907
CHURCH, WILLIAM LEE. Pres. and Cons. Engr., Ambursen Hydr. Constr. Co., 176 Federal St., Boston, Mass		Feb. 6, 1907
HARTWELL, HARRY. Res. Cons. Engr., United Rys. of San Francisco, Oak and Broderick Sts., San Francisco, Cal	Jun. Assoc. M. M.	Jan. 2, 1894 Feb. 2, 1898 Jan. 3, 1907
HARWOOD, GEORGE ALEC. Chf. Engr., Electric Zone Impvts., N. Y. C. & H. R. R. R., Room 1206, Grand Central Station, New York City	Assoc. M. M.	Feb. 5, 1902 Feb. 5, 1907
HERRING, WILLARD E. Const. Engr., U. S. Forest Service, Washington, D. C.	Assoc. M. M.	Sept. 4, 1901 Jan. 3, 1907
HILL, CURTIS. Engr., Sewer Dept., City Hall, St. Louis, Mo	Assoc. M. M.	Oct. 2, 1901 Jan. 3, 1907
KIEFFER, STEPHEN EPHRAIM. Asst. Chf. Engr., Monterey Water Works & Sewer Co., Ltd., Monterey, Mexico	Assoc. M. M.	Oct. 5, 1904 Jan. 3, 1907
LAWSON, THOMAS R. Asst. Prof. of Mechanics, Rens. Poly. Inst., 99 Twelfth St., Troy, N. Y.	Assoc. M. M.	June 3, 1903 Jan. 3, 1907
PARSONS, BURT HEWITT. Prin. Asst. to Hugh L. Cooper, Cons. Engr., 60 Wall St., New York City		Feb. 6, 1907
RUSHMORE, DAVID BARKER. Engr., Power and Mining Dept., Gen. Elec. Co., Schenectady, N. Y.		Jan. 2, 1907

ASSOCIATE MEMBERS.		
BALL, LAURENCE ADAMS. Structural Engr. for Reed & Stem, Archts., 5 East 42d St., New York City	Jun. Assoc. M.	May 3, 1904 Feb. 6, 1907
BURGOYNE, JOHN HENRY, Jr. Care, Josiah Harding, Arica, Chile	Jun. Assoc. M.	Sept. 1, 1903 Dec. 5, 1906

ASSOCIATE MEMBERS—*Continued.*

	Date of Membership.
CHENEY, HERBERT NEAL. 212 Savin Hill Ave., Dorchester, Mass	Feb. 6, 1907
CHEW, RICHARD SANDERS. Structural Engr., Milliken Bros., Inc., 509 Eddy St., San Francisco, Cal	Sept. 5, 1906
DARWIN, WALTON PRUETT. Asst. Engr. to Engr. of Bridges, Dist. of Columbia, 1534 Sixteenth St., N. W., Washington, D. C	Feb. 6, 1907
DE YOUNG, ISAAC. U. S. Junior Engr., Sault Ste. Marie, Mich	Dec. 5, 1906
ELROD, HENRY EXALL. 148 Forest Ave., Dallas, Tex	Nov. 7, 1906
FARNHAM, ARTHUR BENJAMIN. Engr., Board of Public Works, Pittsfield, Mass	Jan. 2, 1907
HOAD, WILLIAM CHRISTIAN. Assoc. Prof. of Civ. Eng., Univ. of Kansas, Lawrence, Kans	Dec. 5, 1906
HOLMES, EDWIN MERRITT. Asst. Supt., The Spanish-Am. Iron Co., Daiquiri, Cuba	Jun. Mar. 31, 1903 Assoc. M. Jan. 2, 1907
HOWARD, CONWAY ROBINSON. Res. Engr., Huntington Div., C. & O. Ry., Box 454, Maysville, Ky	Dec. 5, 1906
INNES, HARRY CLIFFORD. Cons. and Const. Engr., Station R, Cincinnati, Ohio	Feb. 6, 1907
JONES, SIDNEY GARDNER. Asst. Chf. Engr., Big Fork & International Falls Ry. Co., Lock Box 74, Big Falls, Minn	Jan. 2, 1907
LAMBIE, CHARLES SUMNER. 331 Fourth Ave., Pittsburg, Pa	Jun. Oct. 1, 1901 Assoc. M. Feb. 6, 1907
LEE, GEORGE WILLIAM. Chf. Engr., Sundstrom & Stratton, New York City; Address, Fort Edward, N. Y.	Jun. Mar. 4, 1902 Assoc. M. Jan. 2, 1907
MCCONNELL, JOHN LORENZO. Supt. Cons., Sargent & Lundy, 1720 Railway Exchange Bldg., Chicago, Ill.	Jun. April 4, 1905 Assoc. M. Jan. 2, 1907
MCDONOUGH, MICHAEL JOSEPH. Capt., Corps of Engrs., U. S. A., West Point, N. Y.	Jan. 2, 1907
MASSENBURG, WALTER GRAY. Div. Engr., Gulf, Colorado & Santa Fe Ry., De Ridder, La	Jan. 2, 1907
NOERR, ROBERT COLLYER. Designing Engr., Berlin Constr. Co., Berlin (Res., 120 Huntington St., Hartford), Conn	Jan. 2, 1907
PERROT, EMILE GEORGE. 1200 Chestnut St., Philadelphia, Pa.	Feb. 6, 1907
ROBINSON, FRANK MINER. Asst. Engr., West. Pac. R. R., Quincy, Cal	Jan. 2, 1907
SELLEW, FRANCIS LIBBY. Project Engr., U. S. Reclamation Service, Yuma, Ariz	Dec. 5, 1906

ASSOCIATE MEMBERS—*Continued.*

	Date of Membership.
SMITH, CHARLES VERNON. Chf. Draftsman, Hudson Companies, 111 Broadway, New York City	Dec. 5, 1906
STEWART, JOHN WELLINGTON. Care, Norfolk & Southern Ry., Raleigh, N. C	Jan. 2, 1907
TIFFANY, NELSON OTIS, Jr. Engr. and Contr., 428 Ellicott Sq., Buffalo, N. Y	Jan. 2, 1907
WHITMAN, NATHAN DAVIS. Engr., Reinforced Concrete Pipe Co., Jackson, Mich	Dec. 5, 1906
WILDES, WALDO GILMAN. Asst. Engr., State Engr.'s Office, Weighlock Bldg., Syracuse, N. Y. { Jun. / Assoc. M.	Feb. 3, 1903 / Jan. 2, 1907

ASSOCIATES.

DENIO, GEORGE LA PIERRE. 15 East Dayton St., Ridgewood, N. J	July 9, 1906

JUNIORS.

ALLEN, CHESTER SALISBURY. Structural Engr., The Norcross Bros. Co., 10 East Worcester St., Worcester Mass.	Dec. 4, 1906
CARLISLE, ORVILLE BERTON. Structural Draftsman, Milliken Bros., Inc.; Address, 28 Dongan St., West New Brighton, N. Y	Sept. 4, 1906
COOK, JOHN WHEELER. 112 Mead Ave., Passaic, N. J	Oct. 30, 1906
CRAIN, ARTHUR MANCHESTER. Insp., Detroit River Tunnel Co., 498 Brush St., Detroit, Mich	Jan. 3, 1907
DAVIS, CHARLES MOSS. Asst. Engr., U. S. Reclamation Service, Mitchell, Nebr	Jan. 3, 1907
ELTINGE, ORVILLE LAMONT. 67 Middleburgh St., Troy, N. Y	Jan. 3, 1907
FOULDS, ROBERTS SHEPHERD. 216 Morgan St., Phœnixville, Pa	Feb. 5, 1907
GIFFORD, GEORGE HOAG. Fulton St., Hollis, N. Y	Feb. 5, 1907
HAND, RICHARDSON. Rodman, Westinghouse, Church, Kerr & Co., Penna. Terminal, 399 Manhattan Ave., New York City	Jan. 3, 1907
HASBROUCK, OSCAR. Leveler, Barge Canal Office, Albany, N. Y	Jan. 3, 1907
HASELWOOD, FRED WILLIS. Res. Engr., West. Pac. Ry., Altamont, Alameda Co., Cal	Jan. 3, 1907
HILL, GEORGE SAMUEL. 3038 Groveland Ave., Chicago, Ill.	Jan. 3, 1907
LEEDS, CHARLES TILESTON. 1st Lieut., Corps of Engrs., U. S. A., Fort Bayard, N. Mex	Jan. 3, 1907

JUNIORS—*Continued.*	Date of Membership.
LUBARSKY, LOUIS HENRY. 64 West 118th St., New York City	Feb. 5, 1907
MCCLAVE, STEPHEN WOOD, Jr. Grantwood, N. J	Jan. 3, 1907
MERRIMAN, RICHARD MANSFIELD. Transitman, Erie R. R. Co., Central Valley, N. Y	Jan. 3, 1907
SQUIRE, HARRY EDWIN. Care, Scofield Const. Co., Mare Island, Cal	Jan. 3, 1907
TRUE, ALBERT OTIS. 1503 Farmers Bank Bldg., Pittsburg, Pa	Feb. 5, 1907
WATKINS, GUY ANDERSON. Asst. Locating Engr., Atlanta & Birmingham Const. Co., Crocker, Mo	Jan. 3, 1907

DEATHS.

ELDRIDGE, ARCHIBALD RONALDSON. Elected Member October 2d, 1901; died January 17th, 1907.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(January 6th to February 9th, 1907.)

NOTE.—*This list is published for the purpose of placing before the members of the Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles, references are given by the number prefixed to each journal in this list.

(1) *Journal*, Assoc. Eng. Soc., 31 Milk St., Boston, Mass., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City. Issues for first Saturday of each month, 20c., other issues 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générales des Chemins de Fer et des Tramways*, Paris, France.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.

(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 803 Fulton Bldg., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne, England.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Industrial World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(70) *Engineering Review*, New York City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.
(72) *Electric Railway Review*, Chicago, Ill., 10c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, Ill., 10c.
(77) *Journal*, Inst. Elec. Engrs., London, England.
(78) *Beton und Eisen*, Vienna, Austria.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie-Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Dinglers Polytechnisches Journal*, Berlin, Germany.
(83) *Progressive Age*, New York City, 15c.
(84) *Le Ciment*, Paris, France.
(85) *Proceedings*, Am. Ry. Eng. and M. of W. Assoc., Chicago, Ill.
(86) *Engineering World*, Chicago, Ill.

LIST OF ARTICLES.

Bridge.

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The Quebec Bridge.* (12) Jan. 18.
Erection Attachments for Bottom Chords and Vertical Posts of the Quebec Bridge.* (14) Jan. 19.
Bearings for King Edward VII Bridge, Newcastle-on-Tyne.* (12) Jan. 25.
The Las Vacas Viaduct on the Guatemala Railway.* (14) Jan. 26.
The Piney Creek Bridge, Washington, D. C.* (14) Jan. 26.
Erection of the Main Vertical Posts of the Quebec Bridge.* (14) Jan. 26.
The Walnut Lane Concrete Arch Bridge Across the Wissahickon, Philadelphia.* (13) Jan. 31.
Enlarging the Manhattan Terminal of Brooklyn Bridge.* (13) Jan. 31.
The Erection of the Las Vacas Viaduct, Guatemala Railway.* (14) Feb. 2.
New Lehigh Valley Bridge over the Susquehanna River, Near Towanda, Pa.* Philip H. De Witt, M. Am. Soc. C. E. (15) Feb. 8.
Pont Tournant pour la Circulation des Trains Desservant les Voies de Quai du Port de Roanne au-dessus du Chenal de Communication du Port avec la Loire.* Mazoyer. (43) 1906, Pt. 3.
Deuxième Note sur le Calcul des Arcs Encastrés. Pigeaud. (43) 1906, Pt. 3.
Les Ponts de Chemins de Fer en Ciment Armé.* Victor Forestier. (78) Nov.
Die Wallstrassenbrücke in Ulm a. D.* Neuffer. (51) Serial beginning Jan. 9.

Electrical.

New Types of Incandescent Lamps.* Clayton H. Sharp. (42) Dec.
Recent Investigation of Lightning Protective Apparatus.* R. P. Jackson. (42) Dec.
Electric Power Systems in Some European Cities. P. Junkersfeld. (Abstract). (4) Dec.
On the Electric Radiation from Bent Antennæ.* J. A. Fleming. (Abstract of a paper read before the Physical Soc.) (73) Dec. 28.
The Manufacture of Electric Conduits; the Perfecta Works at Birmingham.* (26) Dec. 28.
Long Spans for Power Transmission Lines.* T. L. Kolkin. (26) Dec. 28.
The Works of the Western Electric Company of America.* (12) Dec. 28.
Independent Telephone Development. James B. Hoge. (3) Jan.
Wireless Telegraph Receivers.* S. M. Kintner. (42) Jan.
Electric Power Transmission. Frederick Darlington. (42) Jan.
Mabbs' Electric Elevator.* (86) Jan. 4.
Electric Measurement of Brief Intervals of Time.* (26) Jan. 4.

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Electrical—(Continued).

Alternating-Current Armature Windings and Their Classification.* H. M. Hobart and A. G. Ellis. (73) Serial beginning Jan. 4.
The Installation and Operation of Alternating Current Generators.* (86) Serial beginning Jan. 4.
The Dunston-on-Tyne Flour Mill.* (73) Jan. 4.
The Temperature Coefficients of Gutta-Percha.* K. Winnertz. (Cables.) (From the *Elektrotechnische Zeitschrift.*) (73) Jan. 4
Leakage Currents in the Moisture Condensed on Glass Surfaces.* F. T. Trouton and C. Searle. (Abstract from the *Phil. Mag.*) (73) Jan. 4.
Power Stations of the Citizens Light, Heat and Power Company of Johnstown, Pa.* (27) Jan. 5.
Design of a 12-in. Induction Coil.* Wm. O. Eddy. (27) Jan. 5.
An Electrically-Driven Cycle Factory.* (12) Serial beginning Jan. 11.
The St. Denis Power Station, Paris.* (26) Jan. 11.
Third Rail Construction.* E. Goolding. (73) Jan. 11.
The Measurement of Received Energy at Wireless Stations.* G. W. Pickard. (From the *Electrical Review* of N. Y.) (73) Jan. 11.
The Fleming Direct-Reading Cymometer and its Applications.* (73) Serial beginning Jan. 11.
The Standard Cell. F. A. Wolff and C. E. Waters. (Abstract of paper read before the Amer. Physical Soc.) (27) Jan. 12.
Electric Shovels for Railway and Mining Excavation.* (13) Jan. 17.
The Marylebone Municipal Electrical Undertaking.* (26) Jan. 18.
Traction Permutators.* (Abstract from *L'Industrie Electrique.*) (73) Jan. 18.
The Application of the Electron Theory to Electrolysis. E. E. Fournier-d'Albe. (Abstract of paper read before the Faraday Soc.) (73) Jan. 18.
Polyphase Power Measurement.* C. A. Adams. (Paper read before the Amer. Assoc. for the Advancement of Science.) (27) Jan. 19.
Estimation of Armature Diameter. L. A. Freudenberger. (27) Jan. 19.
Trans-Atlantic Wireless Telegraphy.* (11) Jan. 25.
Electric Heating and its Application to the Fusing and Firing of Refractory Materials. R. S. Hutton. (Abstract of paper read before the Eng. Ceramic Soc.) (73) Jan. 25.
Electrically-Operated Sinking Plant.* W. Philippi. (Abstract from the *Elektrotechnische Zeitschrift.*) (26) Jan. 25.
Hydro-Electric Plant at Kakabeka Falls, Canada.* W. G. Hewson. (27) Jan. 26.
The Leakage Reactance of Induction Motors.* A. S. McAllister. (27) Jan. 26.
The New Wireless Telegraph Station at Nauen, Germany.* L. Ramakers. (19) Jan. 26.
Modern Harbor Cranes.* (27) Jan. 26.
The Installation and Operation of Alternating-Current Generators.* Allis-Chalmers Co. (41) Feb.
The First Atlantic Telegraph Cable. John Mullaly. (3) Serial beginning Feb.
Lighting of the State Capitol at Harrisburg, Pa.* (27) Feb. 2.
Equipment of the Public Service Company of Mooresville, Ind.* (27) Feb. 2.
The Construction of Induction Coils.* Wm. O. Eddy. (27) Feb. 2.
Wiring a Frame Dwelling with Flexible Metallic Conduit.* Thomas W. Pope. (27) Feb. 2.
The Location and Erection of a 100-Mile Wireless Telegraph Station.* A. Frederick Collins. (19) Feb. 2.
Electrical Equipment of the West Virginia Pulp and Paper Company, Piedmont, W. Va.* (27) Feb. 9.
Three-Phase Transformation.* A. S. McAllister. (27) Feb. 9.
Les Lampes à Incandescence de Fabrication Récente.* A. Larnaude. (32) Nov.
Transporteur Aérien à Chariot Electrique Automoteur.* (33) Dec. 29.
Les Usines Electriques du Canal de Dérivation du Rhin en Amont du Lac de Constance.* S. Herzog. (33) Jan. 5.
Télégraphe Imprimeur Rapide, Système Pollak et Virag.* (33) Jan. 26.
Kritik der Bremssysteme bei Elektrisch Betriebenen Hebezeugen. F. Jordan. (48) Serial beginning Dec. 15.
Schutzvorrichtungen für Hochspannungsanlagen.* (82) Jan. 19.

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Modern Floating Dry Docks.* C. A. Cunningham. (7) Dec.
Ship Model Stations. Cecil H. Peabody. (7) Dec.
The Khedive's Yacht *Mahroussa.* (11) Jan. 4.
The Tactical Qualities of the *Dreadnought* Type of Battleship. W. S. Sims. (Abstract of official report.) (11) Jan. 11.
Engines with Lentz Valves for the S. S. "*Rance.*" (11) Jan. 18.
Submarine Signalling by Means of Sound.* (73) Jan. 25.
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Machine for Recording the Vibration of Ships.* Daniel M. Luehrs. (46) Feb. 9.

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The Battleship of the Future.* Forrest E. Cardullo. (46) Serial beginning Feb. 9.
Les Paquebots Géants de la Compagnie Cunard, "*Lustiana*" et "*Mauretania.*" L. Piaud. (33) Dec. 29.
La Fabrication des Plaques de Blindage aux Forges Nationales de la Chaussade.* A. Bizot. (33) Jan. 26.
Vergleichsversuche an Schiffschrauben.* H. Lorenz. (48) Jan. 5.

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The Suppression of Industrial Smoke with Particular Reference to Steam Boilers.* A. Bement. (4) Dec.
Testing of Coal.* A. Bement. (4) Dec.
Newman's Kinematic Apparatus for the Study of Mechanism.* (11) Dec. 28.
Notes on Turbine Erection and Operation. (26) Dec. 28.
The Principles of Friction Clutches.* Herbert Aughtie. (47) Serial beginning Dec. 29.
The Use of Suction Gas Producers for Power Purposes.* N. T. Harrington. (Paper read before the Civ. Engrs. Club of Cleveland.) (1) Jan.
Materials and Properties of Wrought Pipe.* F. N. Speller. (58) Jan.
A Comparison of the Cost of Power as Generated by Different Types of Steam Engines.* (64) Jan.
A Study of the Zeuner Slide-Valve Diagram.* E. S. Hawkins. (64) Jan.
The Continuous Indicator for Rolling-Mill Engine Work.* Robert L. Streeter. (64) Jan.
Straight Line Expansion Diagram.* (64) Jan.
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Some Considerations Affecting the Application of Waste Gases for Power Purposes. F. E. Junge. (64) Jan.
The Choice of Motive Power for the Workshop.* R. E. Mathot. (9) Jan.
The Mechanical Design of Ball Bearings and Roller Bearings.* W. S. Rogers. (9) Jan.
The Transformation of a Retort-House at Lower Sydenham.* (66) Jan. 1.
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Steam at High Pressures and Temperatures.* (11) Serial beginning Jan. 4.
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Burning Bituminous Slack and Lignites.* George P. Hutchins. (27) Jan. 5.
Notes on Distribution and Gas Supply. R. J. Rogers. (Abstract of paper read before the Midland Junior Gas Assoc.) (66) Jan. 8.
The Installation of Centrifugal Pumps.* Wm. O. Webber, M. Am. Soc. C. E. (13) Jan. 10.
The Fulton Foundry and Machine Works; New Plant at Kirkwood, Ga.* (20) Jan. 10.
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The Ferracute Machine Company's Plant.* (20) Jan. 24.
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The Utility of Cleaning Blast Furnace Gas. H. G. Scott. (Abstract of paper read before the Cleveland Inst. of Engrs.) (68) Jan. 26.
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Standard Method of Testing Fuel Gas Appliances.* Henry L. Doherty. (Report of Committee to the Amer. Gas Inst.) (83) Feb. 1.
Bearings and Their Lubrication. Francis H. Davies. (27) Feb. 2.
Boiler Feed-Piping.* R. T. Strohm. (27) Feb. 2.
Rehabilitation of Customers' Piping. John C. D. Clark. (Paper read before the National Commercial Gas Assoc.) (24) Feb. 4.
The American Cast Iron Pipe Company's Foundry.* (20) Feb. 7.
Testing and Purchasing Coal for Steam Plants. A. O. Doane. (13) Feb. 7.
Rivetage en Acier Spécial; Expériences et Comparaison avec l'Acier Ordinaire.* Mesnager. (43) 1906, Pt. 3.
Note sur l'Emploi de la Chaine de Galle et des Chaines Articulées.* Ed. Henry. (32) Nov.
Les Générateurs de Vapeur Leroux. (34) Jan.
Grue-Tourelle de 150 Tonnes à Volée Basculante du Port de Tsing-tao (Chine).* (33) Jan. 5.
La Réparation des Grosses Pièces d'Acier par l'Aluminothermie.* (33) Jan. 5.
Le Chargement des Hauts Fourneaux d'Après les Méthodes Américaines.* Ch. Dantin. (33) Jan. 19.
Les Progrès de l'Automobilisme en 1906, le IXe Salon de l'Automobile, du Cycle et des Sports.* (33) Serial beginning Jan. 26.
La Fabrication des Plaques de Blindage aux Forges Nationales de la Chaussade.* A. Bizot. (33) Jan. 26.
Zur Theorie der Rotierenden Scheiben.* J. Illeck. (53) Dec. 28.
Die Verwendung des Flammofens in der Giesserei, Insbesondere zur Schmelzung von Schmiedbarem Guss.* Dr. Geilenkirchen. (Paper read before the Deutsche Giessereifachleute.) (50) Serial beginning Jan. 2.
Dampfördermaschinen oder Elektrische Fördermaschinen?* Ad. Wallichs. (48) Jan. 5.
Neuere Geschwindigkeitsregler. Fred. Strnad. (48) Jan. 5.
Einiges über das Kalibrieren der Profilwalzen. A Bartholme. (50) Jan. 9.
Die Dampfkessel in den Elektrizitätswerken Londons.* R. Lind. (48) Jan. 12.
Einiges über Stahlwerkskokillen.* R. Lochner. (Paper read before the Deutsche Giesserei-Fachleute.) (50) Serial beginning Jan. 23.
Zwangläufige Ventilsteuerung mit Flachregler.* R. Proell. (48) Jan. 26.

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The Application of Electricity to the Smelting of Iron Ores.* Horace Allen. (47) Jan. 12.
Electric Furnace Methods of Iron and Steel Production. John B. C. Kershaw. (73) Serial beginning Jan. 18.
Blast Furnace Practice at Blaenavon.* George Forster Martin. (Paper read before the South Wales Inst. of Engrs.) (22) Jan. 18.
The New Blast Furnace Plant of the Frodingham Iron and Steel Company.* (22) Jan. 25.
The Blast Furnaces at the Minnequa Steel Works.* Lawrence Lewis. (16) Jan. 26.
The Heroult Electric Steel Process in Practice.* Eichhoff. (Abstract of paper read before the Ver. Deutsch. Eisenhüttenleute.) (20) Jan. 31.
Recent Improvements in the Cyanide Process. F. L. Bosqui. (Paper read before the Amer. Mining Congress.) (45) Feb.
Steel Making at Pueblo.* Lawrence Lewis. (16) Feb. 2.
The Butters Cyanide Plant, Virginia City, Nev.* Claude T. Rice. (16) Feb. 9.
Fabrication des Alliages Ferro-Métalliques au Four-Electrique.* P. Girod. (32) Nov.
Ueber die Fortschritte in der Elektrostahl-Darstellung.* Prof. Eichhoff. (Paper read before the Verein Deutscher Eisenhüttenleute.) (50) Serial beginning Jan. 9.
Der Zusammenhang zwischen Bruchaussehen und Kleingefüge von Stahlproben.* O. Bauer. (50) Jan. 16.
Versuche mit Gusseisen über den Einfluss des Kugeldurchmessers und des Druckes bei der Brinellschen Methode der Härtebestimmung. R. Malmström. (82) Jan. 19.
Das Erste Elektrische Reversierstrassenantrieb, ausgeführt auf der Hildegardehütte.* D. Geyer. (Paper read before the Verein Deutscher Eisenhüttenleute.) (50) Serial beginning Jan. 23.

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A New 4-7 Inch Siege Gun and Carriage.* (12) Dec. 28.
A New Vickers Automatic Rifle-Calibre Gun.* (11) Jan. 25.

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Boilers for Colliery Purposes. F. C. Swallow. (Abstract of paper read before the South Staffordshire and Warwickshire Inst. of Min. Engrs.) (57) Dec. 14.
Coal Screening Plant for the Cawdor and Garnant Colliery Company.* (22) Dec. 28.

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Our Coal. F. Z. Schellenberg. (58) Jan.
A Lesson from the Courrieres Explosion.* Robert H. Dundas. (22) Jan. 11.
Some Problems Connected with Deep Mining in the Lake Superior Copper District.* F. W. McNair. (Paper read before the Amer. Assoc. for the Advancement of Science.) (14) Jan. 12; (19) Jan. 26.
De Beers Consolidated Diamond Mines. Alpheus Williams. (Abstract.) (68) Jan. 12.
Electrical Plant of the Dahlbusch Mine.* Alfred Gradenwitz. (16) Jan. 12.
The Mines at Cobalt.* Reginald Meeks. (16) Serial beginning Jan. 12.
Some Notes on Greenwater.* Edward R. Zalinski. (16) Jan. 12.
The Hydraulic Compressed-Air Power Plant at the Victoria Mine.* D. E. Woodbridge. (16) Jan. 19.
The Raw Materials for Steel Making at Pueblo.* (16) Jan. 19.
Ventilation in Flat Coal Seams.* A. H. Stow. (16) Jan. 26.
A Single Balanced Skip for Lowering in Inclined Works.* S. A. Worcester. (16) Jan. 26.
Copper Mining at Bisbee, Arizona.* Robert B. Brinsmade. (45) Feb.
Lignite of Northeastern Wyoming.* Stewart Kennedy. (45) Feb.
Concrete Mine Models.* W. R. Crane. (45) Feb.
Sulphur Mining and Refining.* L. W. Trumbull. (45) Feb.
A Single-Room System of Mining.* H. S. Gay. (Paper read before the Coal Mining Inst. of Amer.) (45) Feb.
Causes and Prevention of Disasters in Mines. G. Farmer. (10) Feb.
Electrical Winding Plants; Details of Arrangements with Descriptions of Several German Plants.* Alfred Gradenwitz. (16) Feb. 2.
Mining Conditions in the Mountains of Chihuahua.* John B. Farish. (16) Feb. 2.
Coal Mine Fires.* R. V. Norris. (Lecture delivered at Columbia Univ.) (16) Serial beginning Feb. 9.

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Thermometers and Pyrometers; Some of Their Industrial Applications.* Robert S. Whipple. (Paper read before the Syracuse Chemical Soc. and Tech. Club.) (20) Feb. 7.
Le Quatrième Etat de la Matière. Paul Besson. (32) Nov.

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Cement Sidewalk Paving. Albert Moyer, Assoc. Am. Soc. C. E. (67) Jan.
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Driving-Wheel Tire Lathe.* (R. R. shop.) (12) Dec. 28.
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The Art of Manufacture of Railway Car Axles.* Henrik V. von Z. Loss, M. Am. Soc. M. E. (3) Jan.
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Union Switch & Signal Co.'s Switch Controller.* (21) Jan.
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The Use of Oil Fuel for Locomotives.* (Abstract of report to the Traveling Engrs. Assoc.) (13) Jan. 10.
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Development of Tunneling in New York City.* S. D. V. Burr. (20) Jan. 10.
The United Railways of New Jersey.* C. H. Caruthers. (15) Jan. 11.

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THE LOWER COLORADO RIVER AND THE SALTON BASIN.

By C. E. Grunsky, M. Am. Soc. C. E.

To be Presented March 20th, 1907.

Early in 1905 it became apparent to the engineers of the United States Reclamation Service that the Colorado River would change its low-water course; that it would thereafter send its low-water flow and a part of its flood volume inland into the Salton Basin instead of oceanward into the Gulf of California. Ever since that time the Reclamation Service has been an interested observer of the progress made by the canal people (whose operations are responsible for the change of the river's course) in their efforts to curb the river. The observations of the Reclamation Service engineers have been extended also to the changes which have been taking place along the new watercourse.

This paper is based upon the results of these examinations, and is in a measure a transcript of the writer's official reports on this subject.

The point in Mexico where the canal company made the diversion which threatens to become the permanent river channel is

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

about 4 miles south from the boundary line between California and Mexico. It was visited by the writer twice in 1905 and three times in 1906.

In the spring and summer of 1905, the Colorado River—in Lower California at this point, which is some 12 miles below Yuma—enlarged a small artificial channel or cut which connected the river with the Imperial Canal, and also enlarged the canal to such an extent that this so-called canal heading and the canal became the river's low-water channel. The river, in November, 1905, during a flood stage, made this heading and portions of Alamo and New Rivers and certain sections of the canal its main channel. The river thereupon flowed inland for a year, discharging into the Salton Sea instead of holding to its original southerly course with discharge into the Gulf of California, where it belongs, and where its waters have gone for many centuries. The river was turned from this inland course on November 4th, 1906, but could be held in its proper channel only until December 7th, when the protection works gave way. The river is again flowing into the Salton Sea. The Salton Sea is the water of the Colorado River which has accumulated in California in the bottom of the depression (about 278 ft. below sea level at the lowest point) known to geographers as the Colorado Desert, but recently referred to as the Salton Basin.

The canal, which for the present has become a river, was constructed primarily for the irrigation of lands in California in the Imperial Valley, as the southern portion of the Salton Basin is called. This canal is frequently called the Imperial Canal. It is the property of the California Development Company and of a subsidiary Mexican corporation through which the California Development Company has been conducting operations in Mexico.

The original water diversion from the Colorado River, by the California Development Company for the irrigation of lands in California, was made in the southeastern corner of that State within a few hundred feet of the international boundary; but the operations which led to a change of the river's course were entirely within the territory of Mexico, and are presumed to have been conducted under concessions granted by that country to the canal companies.

A continuation of the inland flow of the Colorado River would in time bring disaster to the Imperial Valley. It would further damage the property of the Southern Pacific (railroad) Company, which has already sustained great financial loss, and would ultimately ruin all improved lands in the Salton Basin as well as the lands along the lower sections of the Colorado River. It would modify or destroy the irrigation possibilities along this river below its cañon.

Salton Basin.

"Salton Basin" is the name applied to the region in southeastern California and northern Lower California which will ultimately be submerged if the Colorado River continues to discharge inland instead of into the Gulf of California.

This region extends northward to a point a few miles beyond Indio, and toward the south overlaps the international boundary some 15 to 20 miles. The length of the basin which is thus threatened with submersion is about 100 miles from north to south; its surface area is about 1 950 sq. miles, and its mean width nearly 20 miles.

The lowest point of this basin, at the former salt beds, now more than 70 ft. under water, is 278 ft. below sea level.

The rainfall in the country adjoining this great depression is so slight—only a few inches per annum—that practically no run-off reaches its lowest points. All the water now there, covering more than 400 sq. miles, is inflow from the Colorado River.

The Southern Pacific Company, about 1876, built its main line across this depressed area, dropping to a lowest point near Salton with an elevation—or rather greatest depression—about 265 ft. below sea level. Its main line, from a point several miles north from Indio to near Flowing Well, some 3 miles east from Imperial Junction (formerly Old Beach), is below sea level.

At the salt beds, the Liverpool Salt Company established salt works, apparently a remunerative enterprise, but these beds were completely submerged early in 1905.

At Indio, and southward from this point to near the salt beds, wherever water has been obtainable from adjoining streams or by boring wells, as near Coachella, Artesia and Mecca, the land is being improved, and homes have been established. Before the river



FIG. 1.—DRY BED OF COLORADO RIVER, BELOW LOWER MEXICAN HEADING OF IMPERIAL CANAL. AUGUST 26TH, 1906.



FIG. 2.—SUNSET ACROSS SALTON SEA. FROM NEW SALTON RAILROAD STATION, AUGUST 29TH, 1906.

was turned, these were just beginning to fall a prey to the rising waters of Salton Sea, and are now again menaced.

Since the California Development Company's irrigation work from the Colorado was undertaken, the valley south of the basin's greatest depression has been known as the Imperial Valley. Here towns quickly sprang up, and Imperial, Brawley, Holtville, Calexico and more recently El Centro have become centers of activity.

Mr. W. F. Holt, President of the Imperial Valley Water Users' Association, states that in January, 1905, the population of Imperial Valley was 10 000. It is probable that the number of persons who had homes, real property, or other interests at stake in the valley in its most prosperous days exceeded this number.

Calexico is at sea level, Imperial about 60 to 70 ft. below sea level, and Brawley about 110 ft. below sea level. The surface of Salton Sea is now about 207 ft. below sea level. The rise of the water, therefore, would have to be about 90 ft. before the country near Brawley would be inundated.

Although the Imperial Valley is not yet covered by the waters of Salton Sea, much damage has been done to the lands in this valley by the river water in its flow from south to north along the Alamo and New Rivers. These, particularly New River, were not intended by Nature to carry such volumes of flow as the river discharged into them after it broke from its proper course at the Lower Mexican Heading. Therefore, there were times in 1905 and 1906 when great areas along these streams were flooded, and other areas would have been inundated, except for the protection they received by strenuous work on long lines of dikes or levees. Unfavorably located tracts were sacrificed to save the more fortunate districts, and every effort was bent to increase the carrying capacity of New River along which flood damage was greatest.

The canal system was not planned for such unforeseen flood conditions. Structures were inadequate to safeguard properly the supply to the canals. Constant vigilance was required to keep out the undesirable flood, and to keep, in the canals, an adequate supply for the needs of the irrigators. In fact, many critical periods have been passed. Any untoward accident at Sharp's Heading during the flood stage of the river would have rendered the entire Imperial country untenable. An accident there, such as a wash-out of

the waste-gate which drops water some 20 ft., would have deprived the canal system of water—a serious situation for a region in which even the water for domestic use is supplied by the canals.

But the danger of a general inundation passed when New River, in June, 1906, had carried the head of a great barranca, which it was cutting in the plain, past Calexico and Mexicali, and had drained much of the overflowed region lying to the south of the boundary line. Then the question arose, would the river be turned before this back cutting reached the Alamo above Sharp's Heading, drawing the water from the canals; or would the dreaded water famine have to be faced even while the whole river went rushing by? This question is again pending, now that the engineers at the Lower Mexican Heading have failed to hold the river in its proper channel.

The topographic features of the country make it plain why all this has happend. The river, like all turbid streams, is still building up the alluvial country through which it flows. It drops some of its silt wherever it sends its water. At flood stages, when there is overbank flow, the rate of silt deposit is most rapid near the river. The frequent inundation of the bank lands adds to their elevation more than is added to land farther away. Therefore, here, as should be expected, the land slopes away from the river.

The Colorado River flows southerly in a direction in which the general fall of the ground surface is only about 1½ ft. per mile, which the river in its meanderings cuts down to an effective fall of about 1 ft. per mile.

Toward Volcano Lake, southwest from the river, the general surface gradient is 2 ft. or more per mile; and westward, in the direction paralleling Alamo River, it is nearly 3 ft. per mile to a point near Calexico. Thence northward into Salton Basin, on lines of greatest slope, the country falls away at the rate of from 4 to 5 ft. per mile.

These gradients, which are cross-country gradients and do not show the fall of the water surface following the meanderings of the several watercourses, make it plain that the river while flowing inland must cut deep into any yielding material. Its proper fall was about 120 ft. in its course from Yuma to the Gulf, 80 miles distant, whereas it now falls some 325 ft. to the Salton Sea which.

in the general direction of the water's flow, is only from 5 to 10 miles farther removed from Yuma. The excess of energy represented in these figures has been largely expended by the river in deepening and enlarging its new bed.

Channel cutting and deepening of the river-bed, if the river be not turned, will in time extend up stream far above Yuma, and, in such event, will continue until the rising waters in Salton Sea reduce the excessive river gradients that prevail during the Sea's low stages. Ultimately, if the river flows inland unchecked, the basin waters will overflow at or near Volcano Lake. The river's discharge will then be into the southeastern extremity of the Sea, about 30 miles westward from Pilot Knob, at an elevation somewhere in the neighborhood of 30 ft. above sea level, and the process of delta building at the river's outfall point will recommence on the lake margin and will continue until the river at Pilot Knob is restored to its original height. The time will then come when conditions of slope will be reversed, when there will be greater fall toward the Gulf than toward Salton Sea, and then finally the river will itself resume its course to the sea. Centuries would probably elapse before this would occur.

Early Explorers of the Lower Colorado River.

An expedition sent out by Cortes, Viceroy of New Spain, in 1539, under Francisco de Ulloa sailed northwestward from Acapulco to the head of the Gulf of California. This expedition established the fact that Lower California was not an island, but a peninsula, and that there was probably a great river discharging into the head of the Gulf; but the river was not entered.

A year later, Francis Vasco de Coronado, then Governor of New Galicia, the province north of New Spain, was commissioned by Mendoza, the successor of Cortes as Viceroy, to explore the country to the northwest with the specific purpose of reaching the famed Seven Cities of Cibola. The exploration was to be both by land and sea. Coronado himself led the land party, and Captain Hernando de Alarçon was placed in charge of three ships in which he sailed up the Gulf of California and found the great river, as had been expected. Coronado had already started northward overland. It was evidently expected that the two branches of the expedition

would be in communication with each other, from which fact it appears to be certain that the existence of the great river was more than mere conjecture.

Alarçon succeeded in overcoming the difficulties of entering the mouth of the river, and won the friendship of the Indians, who assisted him in ascending the river in boats, which were for the most part towed with ropes by the Indians. His first journey up stream occupied 15 days, and he returned down stream in less than 3 days. Preparations were then made for a longer absence from his ships, and the river was again ascended probably to some point nearly 100 miles above Yuma. A cross was erected, and messages were left for Coronado, should he reach the river.

Meanwhile, Coronado, who was far to the northeast, had detached Captain Melchior Diaz from the main body of explorers to attempt a junction with Alarçon. Diaz reached the Colorado and learned that boats had ascended the river to a point 3 days' journey below. He reached that spot and found letters from Alarçon who, at that time, however, had already departed from his main camp at the mouth of the river. Diaz made a short exploration to the west of the Colorado River, but the country was too forbidding to promise any result of value.

Concerning the subsequent fate of Diaz, Mr. F. S. Dellenbaugh, in his entertaining narrative, "The Romance of the Colorado River," says:

"A dog belonging to the camp pursued the little flock of sheep that had been driven along to supply the men with meat, and Diaz on his horse dashed toward it, at the same time hurling a spear. The spear stuck in the ground instead of striking the dog, and the butt penetrated the Captain's abdomen, inflicting under the conditions a mortal wound. The men could do nothing for him except carry him along, which for 20 days they did, fighting hostile natives all the time. Then he died. On the 18th of January (1541) they arrived without their leader at the settlement from which they had started some three months before."

Sixty-three years later (in 1604) Don Juan de Onate, a wealthy governor of New Mexico, reached the Colorado River, at the mouth of the Bill Williams Fork, and traveled down the stream to the Gulf.

Padre Eusibio Francisco Kino was the next traveler whose visit

to the mouth of the Colorado is recorded. He crossed the river in 1701, about a day's journey above its mouth, and in the spring of 1702 was at its mouth.

Ugarte reached the mouth of the Colorado by way of the Gulf of California in 1721, and it was again visited in 1744 by Fernando Consay, who ascended the Gulf looking for suitable mission sites.

In 1771 Padre Garces descended the Gila to the Colorado, and continued down the latter probably to its mouth. In 1776 he again journeyed down the river from Yuma to the Gulf.

In 1826 Lieut. R. W. H. Hardy, of the British Navy, in the schooner *Bruja,* sailed up the Gulf and met with some mishaps to his vessel at the mouth of the river. He mistook the channel which now bears the name Hardy's Colorado for the main stream, and thought the river proper was the Gila. He named the islands which lie in the head of the Gulf, Montague and Gore.

Two trappers, James P. Pattie and his father, who had in 1825 made a long journey, paralleling the cañon of the Colorado from the mouth of the Gila up to the river's sources in Colorado and Wyoming, again reached the river in 1827, and, being robbed of their horses by the Indians, decided to make a trip down the Colorado to the settlements supposed to be at its mouth. They made the trip leisurely, but could find no settlements, and were finally turned back by the fierce currents of the ebb and flood tides in the mouth of the river, and after many hardships reached the Pacific Coast.

Ever since 1850 there has been an American settlement on the river at Yuma, and the river has been explored repeatedly above and below that point. Lieut. G. H. Derby, in the winter of 1850-51, made an exploration of the waters at the mouth of the river, and his expedition was met by boats sent down the river by Major Heintzelman then stationed at Yuma.

The first steamboat on the river below Yuma commenced making trips about 1853.

In 1857 Lieut. J. C. Ives, in a small steamboat, *The Explorer,* brought to the river in sections, ascended to Black Cañon, and continued his explorations overland to points on the Grand Cañon.

The records of some of the early explorations are meager, but, when taken in their entirety, the important fact seems to be well

established that the Colorado River has not, for any protracted period in historic times, abandoned its course into the Gulf of California, and that at no time since its discovery, nearly 400 years ago, has there been any general submersion of the Colorado Desert.

This knowledge is valuable because quite recently—in geologic time—there has been a great fresh-water lake covering the desert to an elevation about 30 ft. above sea level. This lake has left its borders plainly marked upon the ground. The beach line is clearly defined and can be traced around the ancient lake bed. An interesting fact in reference to this basin was discovered in 1905, when an outline topographic survey was made of the basin, once full of water, by the U. S. Geological Survey (W. Carvel Hall being in charge of the field work). It was found that subsequent to the time when water had filled this basin there had been an upheaval of the country along its eastern margin to the extent of 20 ft. or more. The beach line, which at the western margin of the ancient lake is about 30 ft. above the sea, is in the neighborhood of 50 ft. above on the eastern margin. No information is at hand as to whether this upheaval was gradual or sudden; but, as there do not appear to be any secondary beach lines below the well-defined ancient beach, it appears reasonably certain that the upheaval was subsequent to the existence of the lake.

Earthquakes.

In connection with this probable uplift on the Colorado River side of the Salton Basin, it may be noted that it is believed that a southern continuation of the great fault line along which there was some movement on April 18th, 1906, both north and south of San Francisco, causing an earthquake on that day, passes southward into the Gulf of California through the Salton Basin. At about 4 P. M. on the day of the San Francisco earthquake, there was an earthquake in the Imperial country, apparently most severe near Brawley. It is reported to have caused considerable breaking down of the high vertical alluvial banks along the newly eroded barranca of New River.

On November 9th, 1852, there was an earthquake in the southeastern portion of California, in southwestern Arizona and in parts of Lower California, of which Dr. Blake (1853) says:

"The earthquake of 1852 (November) was sufficiently violent to break off a piece of Chimney Peak and to open fissures in the clay of the desert."

Referring to the same earthquake, Lieut. J. C. Ives (Exploration of 1857) relates that in November, 1852, a schooner at anchor 30 miles above the mouth of the Colorado River, floating in 14 ft. of water, had an earthquake experience. There was a rumbling sound and a shock, and then suddenly sand arose, leaving the vessel aground with only 3 ft. of water around it. It was floated off by the succeeding spring tides.

The Ancient Lake of the Colorado Desert.

That there was at one time a lake or inland sea of large extent in the Colorado Desert, covering somewhat more than the area which is below sea-level, was recognized by Dr. William P. Blake, the geologist of the exploring expedition for a railroad route from the Mississippi westward to the Pacific Ocean (1853 to 1855). The character of the water which filled the basin is known from the shells still found there in large numbers. It was fresh water, or water only slightly brackish.

There is no doubt that this ancient lake was cut off from the north end of a long narrow arm of the ocean which extended into California to near Indio, and was a northerly continuation of the Gulf of California. At the period, in geologic history, when the Gulf of California thus extended inland some 150 miles farther than at present, the Colorado River had its mouth upon the eastern shore of this great bay at or near the point where Yuma is now located. The river's water surface at that point was then practically at sea level; it is now, varying with the water stage (high or low), from 117 to 130 ft. above sea level.

The river then, as now, carried seaward a large quantity of silt. This quantity is now in the neighborhood of 50 sq. mile-ft. per year (1 ft. deep over 50 sq. miles); in the past, during ages of greater rainfall and greater erosion, it may have been much greater than this. Whatever the rate at which this material was delivered, it has been sufficient in the course of time to build up the present river delta, to push a delta cone entirely across the long bay to the

base of the Cocopah Mountains in Lower California, to push the head of the Gulf southward to a point about 80 miles from Yuma (more than 100 miles by river), and to build up the valley lands in Yuma to their present elevation, about 100 ft. above the sea. The river has thus built a barrier of silt across what was once a great submarine valley. This barrier, which was not the work of a day, but was many centuries in building, trapped the water of the upper end of the prehistoric gulf and created the inland lake.

Subsequent to the formation of this lake, the building up of the river's delta cone continued until the lowest point of the ground (not channel beds) on the broad, flat barrier which now separates the Gulf of California from the Salton Basin was raised to about 30 ft. above sea level.

This elevation of 30 ft. was then, approximately at least, the elevation of the lake water surface.

Referring to this ancient lake, Dr. Blake (1855) says:

"The former existence of a fresh water lake in the northern part of the desert is shown, not only by the extensive deposits of alluvial or lacustrine clay, containing fossils, but by the existence of extended shore lines and beaches along the sides of the bordering mountains."

After alluding to the Indian tradition of great floods which had brought devastation to this region, he says:

"The present outflows, though but very slight, are probably similar, and yet it is possible that the interior of the desert might be deluged at the present day, provided no elevation of the land has taken place, and the river should remain at a great height for a long time—long enough to cause the excavation of a deep channel for New River."

The Indian tradition relating to the ancient Salton Sea is thus given by Dr. Blake:

"The great water (*agua grande*) covered the whole valley and was filled with fine fish. There were also plenty of ducks and geese. * * * Their fathers lived in the mountains and used to come down to the lake to fish and hunt. The water gradually subsided, *'poco,' 'poco'* (little by little), and their villages were moved down from the mountains into the valley it had left. They also said that the waters once returned very suddenly and overwhelmed many of their people and drove the rest back to the mountains."

The River Delta.

It may well be imagined that, in the upbuilding of the delta lands of the Colorado, the river made many changes in its point of outflow. Its mouth swung back and forth between Lake and Gulf, and there may have been many long periods in which its entire flow was either to the one or to the other.

The Colorado Desert was dry or nearly dry once before the long dry period of our own day. This is shown by the mark which the inrushing water that refilled the basin has scored across the valley lands. Then, as to-day, the water cut deep into the alluvial soil, taking a course down the easterly side of the valley and discharging into the remnant of a sea which probably had its southerly margin some miles to the southward of Brawley. The remnant of one of the bluffs of this channel, now a well-defined bank of gradual slope, can be seen some miles east from Imperial.

When an examination is made of the light alluvial material with which the river has built its delta cone, and the ease is considered with which the river cuts the banks in this material, one may well be surprised that it has not long ago resumed its flow into the Colorado Desert, to which course it is invited by the steeper gradients of the surface of the ground in that direction, as above noted. The main force resisting this change is probably the obstruction offered to channel cutting in bank lands by the dense and luxuriant plant growth which is found wherever moisture is available. The growth of vegetation is rank; grasses, weeds, willows, cottonwood and other trees cover the stream banks with a dense thicket through which water cannot flow with sufficient current to cut a channel. Should it happen that an open spot is found and the flow is concentrated across such a spot, then drift will there begin to run, which, by lodging in the brush beyond, aids the silt dropped by the water and soon builds up the open spot to even greater height than the remainder of the bank. Unusual conditions and exceptional combinations of circumstances are required to permit a sufficient concentration of the flowing water, and for such a time and distance that channel cutting can be caused by the overbank flow, anywhere near the main stream.

Whenever a delta slough, a recipient of overflow water, shows a tendency to cut its head closer to the river channel, the resulting

increased overbank discharge toward this point causes rapid accretion to the bank land and a piling up of silt and drift that quickly shuts off the supply of water necessary to advance the new channel farther toward the parent stream.

The various flood-fed streams which flow down the delta cone of the Colorado River westward from its proper channel are therefore without direct connection with this channel. Their waters accumulate in the brush thickets on the bank lands from which they emerge in small streams some miles from the river. A number of such small streams unite to form large watercourses such as the Pescadero River and the Rio Paredones.

The Alamo River was of the same character as these other streams before it was connected with the Colorado artificially.

Reference to the map, Fig. 1, will give a better idea of the location of these several watercourses than can be given in words. It may be stated, however, that the several channels which cross the international boundary line from Mexico into the State of California, were by early travelers referred to as New River or branches of New River. The name Alamo is now applied to the watercourse which, heading in Mexico some 8 to 12 miles southeast from Pilot Knob, was fed by overbank flow from the Colorado River, holds a western and northwestern course along the base of the sand hills lying to the north until it enters California about 40 miles in an air line westward from the Colorado; continuing northward, it empties into the Salton Sea. This river, or some portion of it, is sometimes referred to as Carter's River and as Salton River.

In the mesquite and arrow-weed thicket at the original head of the Alamo, there was an occasional accumulation of so much water, and submersion of so much land, that the locality was called "the Lagoons" (*Las Lagunas*). Although these lagoons received water at practically every high-water stage of the river, they did not always yield enough to the Alamo River to produce a flow throughout the river's entire length. In other words, there were many years in which the Alamo did not discharge any water into the lowest portion of the Salton Basin.

The lagoons, in addition to feeding the Alamo, appear also to have been one of the sources of supply for the Rio Paredones. This stream, which is also known as Quail River and as Middle River

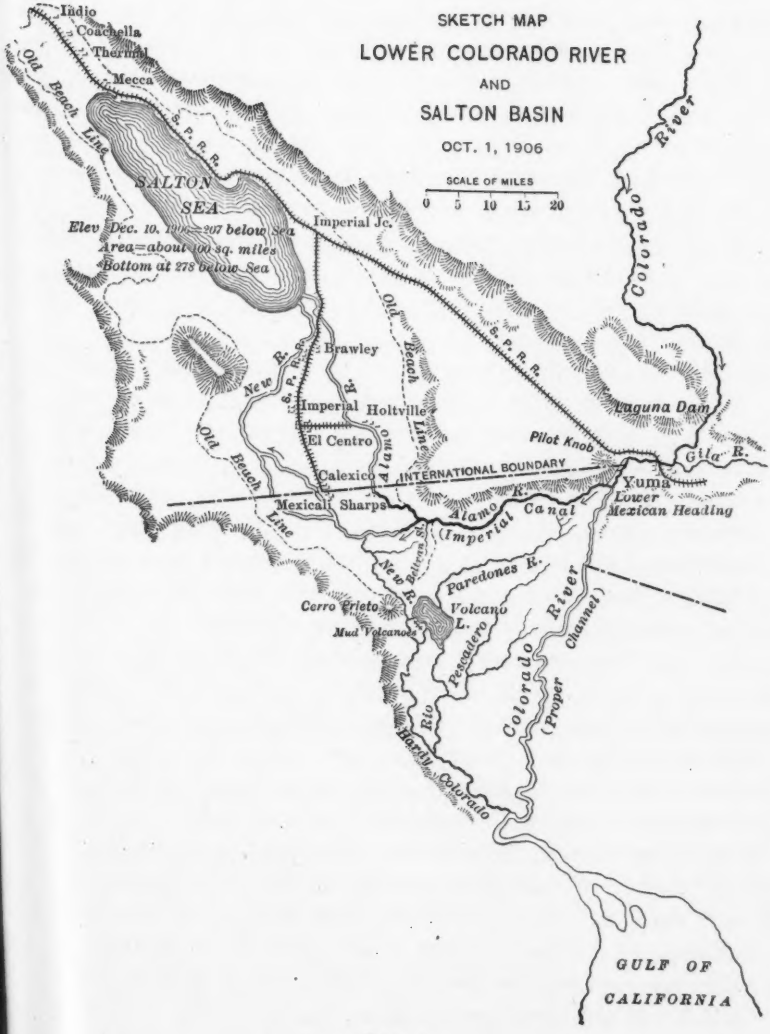

SKETCH MAP
LOWER COLORADO RIVER
AND
SALTON BASIN
OCT. 1, 1906
SCALE OF MILES
0 5 10 15 20
Indio
Coachella
Thermal
Mecca
Old Beach Line
S. P. R. R.
SALTON SEA
Elev. Dec. 10, 1906=207 below Sea
Area=about 400 sq. miles
Bottom at 278 below Sea
Imperial Jc.
Colorado River
Brawley
New R.
Imperial R.
Holtville
El Centro
Old Beach Line
Laguna Dam
Pilot Knob
Gila R.
Calexico
INTERNATIONAL BOUNDARY
Yuma
Mexicali
Sharps
Alamo R.
(Imperial Canal)
Lower Mexican Heading
New R.
Paredones R.
Cerro Prieto
Volcano L.
Mud Volcanoes
Pescadero
Colorado River (Proper Channel)
Rio Hardy
Colorado
GULF OF CALIFORNIA

FIG. 1.

(*Rio Medio*) takes a southwesterly course down the backbone of the delta cone. The water which overtops the right bank of the Colorado at points from 5 to 10 miles below Pilot Knob is the principal source of supply for the feeders of Rio Paredones. The Spanish word, *Paredon,* means big wall. The name of the river, therefore, implies high banks or a well-defined channel, which is true at least of certain portions of the watercourse. It flows practically on the crest of the divide between the Gulf and the lake, and terminates at Volcano Lake, which is probably the remnant of a broad outflow channel which at one time connected the ancient Salton Sea with the Gulf. At freshet stages of the Colorado the Paredones channel may be surcharged, and it then spills water overbank to the south into feeders of Pescadero River and to the north into feeders of New River.

Volcano Lake is crowded against a low, narrow bench at the base of the Cocopah range of mountains. Its bed is at an elevation of about 15 to 20 ft. above sea level and its high-water stage is about 22 to 25 ft. above sea level. The bench land to the west has probably been built up by the mud volcanoes which are still active along the western margin of the lake. These are of the well-known type of solfaternos, and present the usual characteristics of hot mud springs. Well-traveled Indian trails to several pools of moderately hot mud indicate their popularity as a cure for rheumatic ills. They are located at the base as well as on the top of the raised area above designated as a bench. Some of them are submerged at high lake stages. Their activity seems to be somewhat intermittent. During the one night that the writer camped among them, their puffing, blowing and sputtering were vigorous and quite general in the evening and during the early hours of the night, but they were very quiet early in the morning. The outlying springs frequently take the form of miniature volcanoes, perfectly cone-shaped, about 3 to 5 ft. high, with steam issuing from small (6 to 9-in.) circular openings in the top. In many cases a cone of this character has a shattered side, and the bubbling mud is held in place by a rim of caked material extending out from the side of the original cone. In other cases the boiling mud forms large pools in which there are spots of special activity. The bursting of gas bubbles, sometimes

a foot or more in diameter, throws the mud several feet into the air in great thin semi-liquid slabs.

The main outlet of Volcano Lake is Hardy's Colorado, which flows from the southwest extremity of the lake and joins Colorado River just above its entrance into the Gulf. Pescadero River, already referred to, is tributary to Hardy's Colorado. Hardy River, where it leaves the lake, is a channel several hundred feet wide and probably 15 or 20 ft. deep at high stages.

Volcano Lake has a secondary outlet toward the north. This is the channel to which the name New River has in recent times been restricted. New River, at the lake margin and for some distance toward the north, is not a waterway of large capacity. Its bed is not as low as that of Hardy's Colorado. Less than ¼ mile from the lake, this channel sends off a branch, Salt Slough, toward the south, to a union with Hardy's Colorado. The mud volcanoes lie upon the high ground between the Salt Slough and Volcano Lake.

The part of New River near Volcano Lake, Salt Slough, Volcano Lake, and Hardy's Colorado, are possibly remnants of the waterways which connected the ancient Salton Sea with the Gulf. New River northward from this point was originally a rather ill-defined channel, here and there lost in mesquite thickets. It held a course northward from Volcano Lake to the salt beds of the Salton Basin. Its flow was irregular, depending upon the duration of the high-water stages of the Colorado River and the amount of the overflow which reached the Alamo and Rio Paredones. The river is the recipient of the water draining from the low area which lies between these two rivers. Therefore, it receives the overbank discharges of the Alamo toward the south, and of the Paredones toward the north. These discharges were ordinarily of no great moment, but since the river has made the Alamo its main channel and the natural capacity of the Alamo has been restricted by the structures maintained at Sharp's Heading, there has been a large flow of water overbank from this river. The lower section of New River has become the channel for the delivery of this water into Salton Sea. New River crosses the international boundary about 8 miles west from the point where this boundary line is crossed by the Alamo. The small towns, Mexicali and Calexico, are adjacent to

each other upon the two sides of the boundary line and on the east bank of New River. Before the changes in the character of the river-bed which took place during 1906, the river had no well-defined channel at this point; it occupied a broad swale, pushing its way through the open spots in the scattered growth of mesquite, and the water which it ordinarily received was for the most part lost by seepage and evaporation before reaching the salt beds.

But there have been occasional seasons in which extraordinary flood conditions prevailed; and Alamo and New Rivers became flowing streams and the salt beds a lake of water. Lieut. Bergland learned from residents on or near the Colorado (1875-76) that in the years 1840, 1852, 1859, 1862, and 1867 there had been great floods of this character in the New River country, and refers to an account by a traveler in the desert in 1862 who reports having seen in the Salton Basin a great lake 60 miles long and 20 miles wide. This, of course, is an over-estimate of size, as it would have taken the river many years to send overbank enough water to flood so large a portion of the basin. To the high-water years mentioned by Lieut. Bergland others may now be added. Professor Blake refers to the year 1849 as having been reputed the first in which the Colorado sent an overbank flow into the New River country. He recognized at once, however, that this must have happened many times before. In February, 1891, the Colorado rose to an unusually high stage, the water at that time being contributed mainly by the Gila and its tributaries. It overtopped its banks below Yuma, and submerged large areas along the Alamo and New Rivers. Enough water reached the salt beds to submerge them and to cause much speculation by the uninformed as to the source of supply for the lake which had suddenly made its appearance. The years 1905 and 1906 are also to be added to the flood years, but the original conditions of temporary overbank flow during freshet stages have been modified, the river having elected during these years to discharge inland instead of to the Gulf.

The Irrigation of the Colorado Desert.

The reclamation of the Colorado Desert in California by irrigation is not a new idea. Prompted by the project of Dr. O. M. Wozencraft and his associates, the Legislature of California in 1859

adopted a memorial to Congress requesting that 3 000 000 acres of land, the southeastern portion of California, be ceded to the State for reclamation by irrigation. It was proposed, on the basis of this expected cession, to authorize the construction of irrigation works by a private corporation, and the location of a canal partly in Mexico was apparently not considered a formidable obstacle. On this application of the State, the Committee in the House of Representatives made a favorable report (1862), but the measure failed to pass, presumably due to the objection of the Commissioner of the Land Office, who looked upon the scheme as one put forth for the prime advantage of its promoters.

It is of interest, however, in connection with this application for a cession of land, to learn from the testimony of Dr. Wozencraft that the lands of the Colorado Desert were to be reclaimed by irrigation, and that his engineer, Mr. Ebenezer Hadley, County Surveyor of San Diego County, in reporting on this project, recommended a canal location which was practically identical with that actually adopted more than 40 years later. Mr. Hadley said among other things that irrigation was practicable, as water from the Colorado River flows there now. He stated that he had found by actual survey that there was a fall of 5 ft. per mile available along the proposed canal route. He called attention to the necessity of carrying water through Mexican territory. He proposed a canal, 25 ft. wide and 10 ft. deep, which was to tap the river at the point of rocks adjoining Pilot Knob and immediately above the international boundary line. This is probably the exact point at which the California Development Company has recently constructed a concrete headgate. Referring to the names of the natural channels of the New River country, Mr. Hadley says:

"Water having passed through one of these channels from Colorado River soon after our acquisition of the country it was called New River; the other may be justly called Old River."

On this subject of New River, Dr. Blake, on December 5th, 1853, wrote:

"We passed two canal-like channels or wide gullies in the surface, with mesquite trees growing in the bottom, and evidences of the presence of water at a former period. Shells of 'anodonta' and small spiral shells were abundant. These channels probably com-

municate with the two lagoons, and may be the bed of the stream called New River, so-called from the fact of its sudden appearance in 1849. At that time the Colorado River was very high, and broke over a part of its banks between the mouth of the Gila and the head of the Gulf. The water flowed inland, running backward through the desert toward the center of the valley once occupied by the ancient lake; thus proving the valley to be lower than the banks of the river at the place of the overflow. Major W. H. Emory, and party, who crossed the desert from the Colorado to Carizo Creek in 1846, does not mention this stream or any indication of its pre-existence. He mentions, however, that he was informed by a Mexican that a running stream would be found a league west of the Alamo (*Alamo Mocho,* a camping place).

"Parties were sent out to search for the water, but no stream could be found. The appearance of the stream in 1849 was a subject of general surprise and wonder; and was an unexpected relief to the many emigrant parties who crossed the desert that year. It is the general belief that this overflow was the first of its kind, but it has evidently often taken place before."

Dr. Blake, further, says of New River:

"It derives its supply from the Colorado River only at high water, and is probably fed through numerous and ramified channels of slight depth. The precise locality of the entrance of the stream is not known; this renders it more probable that there is not a well-defined channel at the Colorado, but that the water spreads over the banks and afterward collects in one channel."

The feasibility of diverting water from the Colorado at or below the lower end of the Grand Cañon was investigated in 1875 and 1876 by Lieut. Eric Bergland, Corps of Engineers, U. S. Army, who acted under the direction of Lieut. George M. Wheeler. His investigations disclosed the difficulty of locating a diverting canal on United States territory, and he reached the conclusion that the most feasible route for a canal would be below the boundary line. The following is from his report:

"Below the Purple Hills there are no formidable mountain ranges on the west side of the river, except a short detached range, called the Cargo Muchacho, and Pilot Knob. The divide between these mountains is about 278 ft., while the altitude of the water-surface at Fort Yuma is 120 ft. A canal through this opening would therefore require a cutting of nearly 160 ft., and, besides, would have to cut through the sand ridge west of Pilot Knob in



FIG. 1.—ALAMO RIVER, AT HOLTVILLE RAILROAD BRIDGE, AUGUST 31ST, 1906.

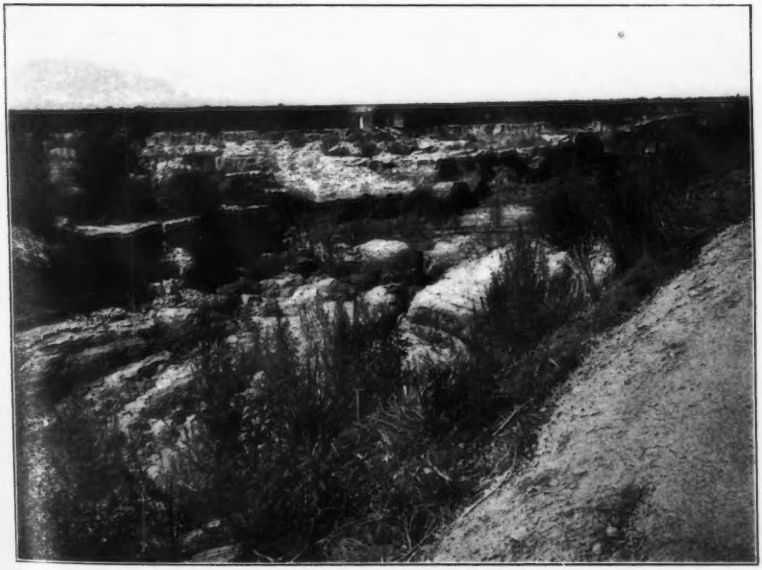


FIG. 2.—THE RUINED FIELD, NEAR NEW RIVER, ABOUT 4 MILES NORTHWEST OF CALEXICO, SEPTEMBER 2D, 1906.

order to gain lower ground more rapidly than by keeping to the north of the sand-hills. Even in this case the length of the canal from Fort Yuma to the point where the surface of the ground is of the same altitude as the water-surface at the latter place would be at least 30 miles long.

"These conclusions are arrived at from data obtained from the Texas Pacific Railroad surveys, and also from levels run by my party from Hanlon's Ferry over the divide north of Pilot Knob. In order that the canal should be entirely within the California boundary, it must cross the divide to the north of Pilot Knob. This, as has already been shown, would necessitate a long, deep cutting, partly through rock, and a passage through the sand ridge. This passage could only be effected by means of a flume or tunnel, to protect it from filling up with sand. A canal from some point below the boundary would be more practicable and less expensive in construction and maintenance. A line of levels was run from Fort Yuma to Indian Wells, and to the dry canal beyond. * * * * * One of the branches of New River leaves the Colorado near Algodon station, and this artificial (natural?) channel might be utilized in the construction of a canal for diverting the water of the river into the depressed area to the northwest. The exact course of this canal cannot be determined without further surveys, but it seems probable that it would be necessary to run it below the boundary-line nearly as far as Seven Wells in order to avoid the sand ridge. From this point it could bend more or less toward the north, according to the downward slope of the surface in that direction. The amount of cutting required is difficult to estimate without further surveys, but it would doubtless be moderate, as the water flows into this area from the river when it overflows its banks."

Notwithstanding this report, which was discouraging to all who had hoped that water could be supplied to the desert in a canal located, throughout its entire length, in United States territory, the promoters of irrigation enterprise continued to look with longing eyes toward a project which would make the desert a garden spot. The region to be irrigated was well known to travelers. It was an uninhabited, grassless, barren plain. Its productiveness when water was made available could be taken for granted. It is an almost rainless region, with warm summer and mild winter climate. Its flat surface and light uniform gradients rendered it particularly attractive to the irrigator.

Finally, Mr. C. R. Rockwood and his associates conceived and carried out the idea of excavating canals on privately owned lands

in Mexico. This was done apparently without any franchise from the Mexican authorities. The water diverted from the Colorado River in California, in a short canal only a few hundred feet long, arriving at the boundary line near the Colorado River, was allowed to fill an extension of this canal on Mexican territory which discharged into the Alamo River a few miles farther on. The natural flow of the Alamo was westward and northward into California where the water was required for irrigation. The canals to distribute this water to the several districts to be covered could be taken out of the Alamo most conveniently in Mexico, and so a secondary diversion was made from this stream, and the heads of several canals which flow into the Imperial country were located south of the line in Mexico. All necessary works in Mexico were located upon land owned or controlled by the canal companies, and the entire course of the Alamo in Mexico was through this land. International questions were thus suppressed or held in the background.

Apparently with this idea of avoiding the necessity of securing concessions from Mexico, and of suppressing international questions, the Colorado River Irrigation Company was organized (1892), and surveys were made and works were planned to deliver water in Mexico and in the Salton Basin for irrigation and domestic use; but the necessary financial backing was lacking, and this company, after several years of preliminary work, failed. Through the further efforts of Mr. Rockwood, a second corporation, the California Development Company, was organized (April 24th, 1896) under the laws of New Jersey, and became the successor in interest of the properties of the earlier company. At the head of this company, managing it and directing its fiscal affairs, was the late Mr. A. H. Heber. He remained at its head until the reorganization in June, 1905, which put the control into the hands of the Southern Pacific Company.

To carry out the plan of constructing canals in Mexico on land controlled by the Development Company, a Mexican corporation was formed—*"La Sociedad de Irrigacion y Terrenos de la Baja California (Sociedad Anonym)"*—which is presumably the same corporation which subsequently received a concession from Mexico —*"La Sociedad de Riegos y Terrenos de la Baja California (Sociedad Anonym)."* All the corporation stock of this Mexican cor-

poration was, and presumably still is, owned or controlled by the California Development Company.

The Mexican Company thereupon acquired from Guillermo Andrade, who was owner of a colonization concession, a tract of land, 100 000 acres in area, which extended along or near the international boundary westward from the Colorado River to beyond the point where the Alamo crosses the line, excluding along the boundary only the barren sand hills projecting over the line from California. There was also an agreement made for the purchase by the Company from Andrade of an additional 100 000 acres.

On the land thus brought under the control of the Mexican company, canal construction was carried on in Mexico, without interference by Mexican authorities. Water was made available for the Imperial lands in 1902 (a small quantity only as early as 1901).

Although Mexico did not make any objections to the use of land within that country as a right of way for carrying water into the United States, there is, it is understood, a protest on file in the Department of State against the diversion of water from the Colorado River (November, 1901); and in this protest the possibility of the whole flow of the river being turned by the proposed irrigation works is pointed out.

The original notice of intention to divert water from the Colorado River in California bears the date, April 25th, 1899. The quantity of water claimed under this notice was 10 000 cu. ft. per sec., and the place of the proposed diversion was referred to as about 1¼ miles above the international boundary line. Actual diversion was made at Hanlon's Crossing, much nearer to the boundary.

The canal of the California Development Company, as originally constructed, had its head in California about 100 yd. north from the international boundary. The canal was cut out from the river at an oblique angle, and its flow was controlled by a wooden structure placed across the canal several hundred feet from the river bank. On a falling river the head of the canal and the gate were obstructed by silt deposits, and it became difficult to keep the water flowing from the river into the canal.

These silt accumulations in the head of the canal interfered with its successful operation, and water shortage resulted in the Imperial Valley in the fall of 1903, and continued throughout 1904.

Probably with the view of adding value to its properties, and thereby improving its financial standing, the company in 1904 sought to secure from Congress a grant of a specific quantity of water from the Colorado. In this it failed, and it also failed to have Congress declare the river non-navigable. Upon application to the Mexican government, however, a concession was made by that country to the affiliated Mexican corporation, under which operations on Mexican territory were legalized, and it was made possible to construct the works which in operation have proven so disastrous.

The original canal was carried from California into Mexico, and paralleled the river for a distance of about 4½ miles, being at no point much more than ¼ mile from the river bank. Its course then changed from south to southwest and west. It passed close along the south base of the sand hills which hang on the south spur of Pilot Knob, and its first section terminated with a length of about 11 miles at the lagoon. Thence the canal water was carried in an artificial channel northwestward to a well-defined section of Alamo River, and flowed in this river to near the point about 40 miles west of the Colorado, where the Alamo enters California. There, about 1 mile south from the international boundary, water is diverted from the Alamo into a number of irrigation canals.

This point, known as Sharp's Heading, had been selected as the proper place for the main diversion of the water from the natural channel into the canals which were to command the Imperial country. Other diversions were maintained, for a time, farther down stream—at the Eastside levee, several miles above Holtville, for the irrigation of District No. 5, and at the Rose levee, several miles below Holtville, for the irrigation of lands in the northeastern portion of District No. 1. But imperfect control of the inflow into the canal head at the Colorado, with consequent flood conditions along the Alamo when the Colorado was high and much surplus water was passing Sharp's Heading, resulted in the repeated destruction of these levees or diverting dams, and led to their abandonment. The entire section of the Alamo below Sharp's Heading was thereafter used as a waste channel.

It would be useless to attempt a minute description of the works

constructed from time to time to keep the improved lands supplied with water. It will suffice to state that at present there is no other point than Sharp's Heading on the Alamo at which a diversion is made from this channel for the irrigation of the Imperial lands.

Districts Nos. 5 and 7, which lie upon the east side of the Alamo, have canals heading at Sharp's. Imperial Canal No. 1 is the original main canal, on the flow of which most of the land between the Alamo and New Rivers (Districts Nos. 1 and 4) is dependent, and it too has its head at Sharp's; so, also, does the Wisteria Canal which at present supplies water only to lands in Mexico belonging to the California and Mexico Land and Cattle Company. Districts Nos. 6 and 8, lying on the west side of New River, are at present entirely without water.

The shortage of water in 1903 and 1904, due mainly to the choking of the canal head with silt, impelled the company to secure from Mexico, as already related, for its affiliated Mexican corporation, a concession under which diversion could be made from the Colorado River in Mexico. This concession was granted, under date of May 17th, 1904, and received the approval of the Mexican Congress in the following month.

The right to divert 10 000 cu. ft. per sec. from the Colorado River on Mexican territory was granted, subject, however, to the use of one-half of this quantity on demand upon lands in Mexico.

The right was also granted to receive this water from a canal heading in California north of the boundary line, and to convey it in canals or natural channels through Mexico. It is required under this concession that plans and profiles of canals already built in Mexico be filed, and that additional works be approved by the Mexican authorities before construction. All work done is to be subject to the inspection of an engineer. The company is required to pay to Mexico $300 per month perpetually. Bridges are to be constructed for road crossings. The company is permitted to import, free of duty, instruments, machinery and the like for use on canal work. The company is exempted from taxation for 10 years, except in the matter of stamps. It is prohibited from selling or mortgaging its property to any foreign government or State, or from taking such government or State into partnership. A deposit of $10 000 in

Mexican bonds was required. It was also made a condition that the corporation holding this concession must be a Mexican corporation, but that any or all stockholders might be foreigners.

Operating under this concession, there was constructed just south of the international boundary a cut less than 100 yd. long from river to canal. This connected with the canal below its original timber headgate, but did not materially improve the inflow conditions. Thereupon a second connection in Mexican territory was made between river and canal. This was about 4 miles south of the boundary line. It is reported to have been first put into use on October 26th, 1904.

Neither of these connections between river and canal, commonly referred to as the Upper and Lower Mexican Headings, was provided with regulating gates. Both were already in use before, on August 28th, 1905, the canal plans were approved by the Mexican authorities. Both were simple dredger cuts of moderate depth and width. The Upper Mexican Heading, like the original canal head in California, showed a pronounced tendency to silt up. The Lower Mexican Heading, on the contrary, which came into use as a channel from 40 to 50 ft. wide and from 6 to 8 ft. deep, had sufficient fall from river to canal (reported at upwards of 1.5 ft. in about 1 300) to give the water a scouring velocity. The bed of this heading was enlarged by the flow through it, but this, at first, caused no alarm. Large canal capacity was desirable, and natural erosion of the channel would reduce the ultimate cost of construction; but soon a time came when the progress of this channel enlargement was too rapid, and measures had to be taken to shut off the flow at the intake. The first proposition seems to have been to place a controlling gate in the canal just below the point where the Lower Mexican Heading joined the canal. The spring rise of 1905, however, came early, and this idea was abandoned as impracticable. Effort was then made to close the heading at the river. Piles were driven, brush and sand bags were used in large quantities, but as rapidly as the structure was pushed from the north side of the heading toward its south side the south bank was cut away by the river's swirling waters. Meanwhile, the river had attained its high stage (June, 1905), and the canal company was in the throes of a reorganization. The first attempt to close the heading

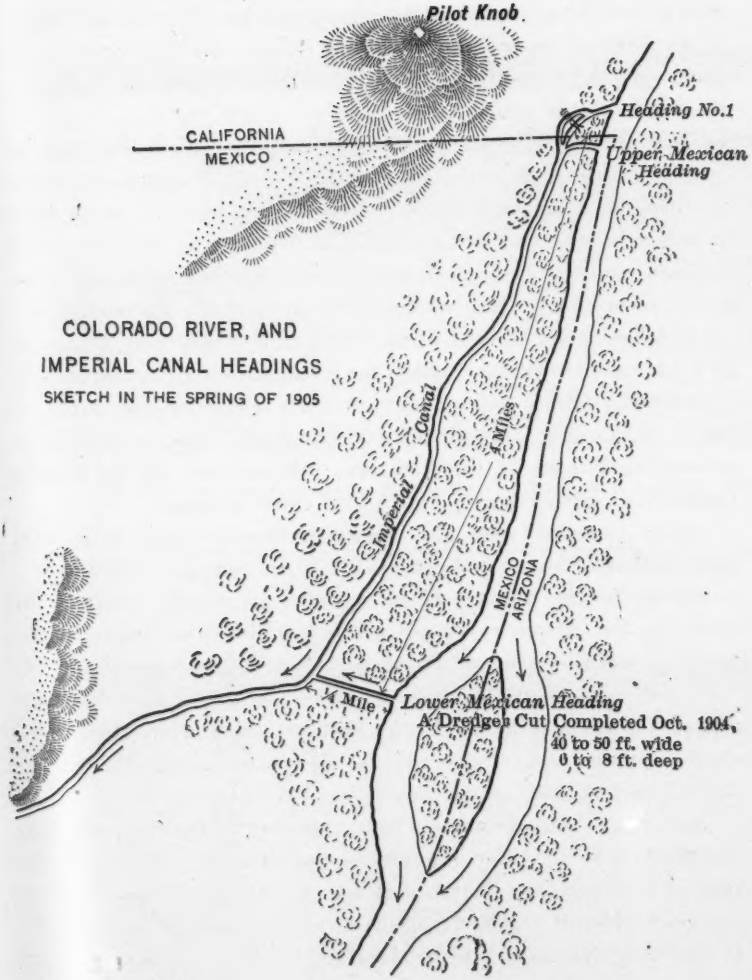

Pilot Knob
CALIFORNIA
MEXICO
Heading No.1
Upper Mexican Heading
COLORADO RIVER, AND
IMPERIAL CANAL HEADINGS
SKETCH IN THE SPRING OF 1905
Imperial Canal
4 Miles
MEXICO
ARIZONA
1 Mile
Lower Mexican Heading
A Dredged Cut Completed Oct. 1904,
40 to 50 ft. wide
6 to 8 ft. deep

FIG. 2.

was abandoned. It was at this time that the direction of the work relating to the checking of the excessive flow into the canal was assumed by the railroad people. The railroad officials, as already stated, had recognized the importance of effecting a speedy control of the flow of water into the Salton Basin, and preferred to take charge of the work themselves, rather than let it be continued by the former canal management.

The situation in parts of the Salton Basin, due to the large inflow of water which was far in excess of channel capacities, had in the meantime become serious. There was already so much water on the salt beds that the Liverpool Salt Company was put out of business, and was making all haste to ship the last of its salt stores out of the country. The rising waters were at the base of the railroad embankment (end of June, 1905), and it was only a question of a few days before the roadbed for a length of many miles must be abandoned. Quick action, and an early check of the inflow of water would save the railroad great expense. Strenuous effort to accomplish this result, therefore, was justified, and led the railroad company to extend financial aid to the canal company.

Other interests were also menaced, however, and there were other sufferers from the flood conditions in Imperial Valley.

Structures at Sharp's Heading were in danger; those lower down on the Alamo could not withstand the flood stages of the river. Lands adjoining the Alamo and New Rivers were submerged. The threatened inundation of the main body of improved lands was prevented only by strenuous work on dikes which forced the water westward into the broad flat depression along New River. Much improved land along New River was inundated.

And all the time (summer, 1905), even while the river was falling, the volume of water presented for passage into the Salton Sea kept increasing. The Lower Heading, in the latter part of June, had been widened to 100 ft. or more, with a depth of about 20 ft. It was then discharging about 7 000 to 8 000 cu. ft. per sec., and it was but a short time before this flow was doubled. It became evident early in July that, if not checked, the river would make the Lower Mexican Heading its low-water channel.

Not only did the river do this, but it increased the canal ca-

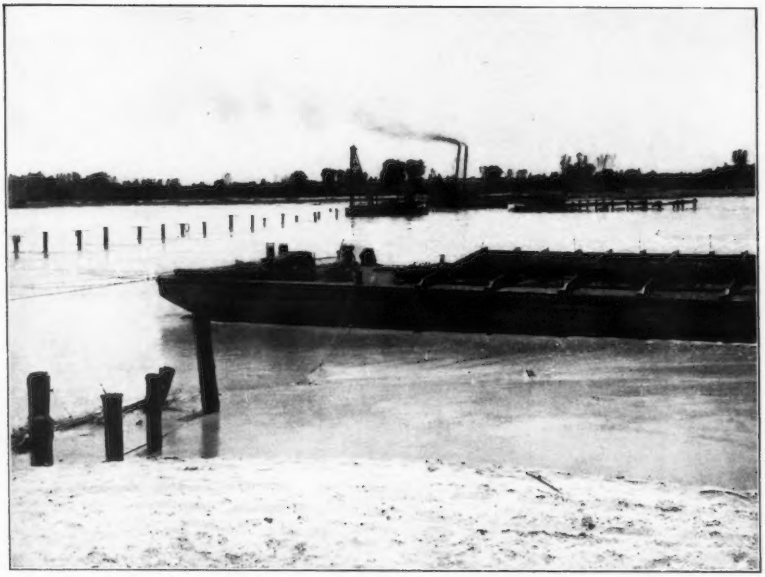


FIG. 1.—VIEW ACROSS ENLARGED LOWER MEXICAN HEADING OF IMPERIAL CANAL, AUGUST 26TH, 1906.



FIG. 2.—PILING FOR RAILROAD TRACK ACROSS ENLARGED LOWER MEXICAN HEADING, IMPERIAL CANAL, AT SITE OF PROPOSED DAM, AUGUST 26TH, 1906.

pacity to such a degree that the canal during the flood stage of November and December, 1905, became the main channel of the river.

Turning the Lower Colorado River Back into Its Proper Channel.

Soon after the failure of the first attempt by the canal companies to stop the flow into the lower heading, they made a second attempt. This was an effort to force the entire river into a channel east of an island in the Colorado River opposite the Lower Mexican Heading. This island was narrow, and about a mile long. It divided the stream into two branches, of which, before the construction of the heading, the eastern branch had the greatest depth and carried the most water. It was proposed to close the western channel at the head of the island. Here, also, piles were driven, obliquely out from the river's right or western bank toward the head of the island, and brush and sand bags were used to check the flow of water. Three times at this point the river defeated the engineers, and impressed upon them the difficulty of the problem. Thereupon what is generally referred to as the third attempt to conquer the stream was made. This was in the fall of 1905, and the point at which the attempt was made was about 1 000 ft. below the head of the island. Here the construction of a dam with a broad brush mattress foundation was undertaken. Mats of brush, having a width of 100 ft. in the direction of the stream, were placed from bank to bank across the western channel of the river. Piles were driven in three rows through these mats, which were about 18 in. thick, and more brush was woven between these piles. This work is reported to have been making fair progress, notwithstanding a stage of the river considerably higher than the ordinary stage for that time of year, when the unexpected happened. A flood occurred on the Salt and the Gila Rivers, and a tremendous volume of water was suddenly discharged into the Colorado River at Yuma. In a few days the river rose from a low stage to become a raging torrent with a maximum discharge, on November 30th, of more than 100 000 cu. ft. per sec. This water overtopped the island. It cut around the eastern end of the incomplete dam and tore away the head of

the island. It quickly cut the heading to a width of several hundred feet and gave it all the appearance of a permanent section of the main river.

This failure, so late in the fall, and the stages higher than ordinary which the river would maintain during the following winter, left the canal officials no hope of accomplishing any results without thorough preparation. It was determined, therefore, that the next attempt should be supplemented by some by-pass arrangement. A channel was to be prepared with a controlling gate through which the river, at a low stage, could be turned. Thereupon the river was to be obstructed by brushwork until its entire flow was forced through the by-pass. The brushwork dam would then receive earthwork reinforcement and be connected with levees or dikes up and down the river so that finally a closing of the controlling gates would raise the water high enough to force it to take its course, where it belonged, down the old channel of the river to the Gulf.

Two points appeared to be available in carrying out this by-pass idea, the one involving least expenditure of time and money being at the Lower Mexican Heading; the other was at the original canal heading in California. It was believed by the engineers in charge of the work that at the lower point a large gate, a timber structure, could be constructed and would be ready for use in April, 1906, when it was hoped that the stage of the river would still be low enough to justify an attempt to put a brush dam across the river. The success of this project depended upon the completion of the gate in time, and upon favorable river conditions for some weeks after its completion.

At the other point, which is several hundred feet up stream from the original canal head in California, the plans involved the construction of a large gate which it was planned should ultimately become the permanent canal headgate. From this gate an excavation of sufficient capacity to take the entire river flow at its low-water period was to be made southward, paralleling the original canal and terminating 4½ miles below in what was formerly canal, but had temporarily become river channel. As this gate was to become a permanent feature of the canal system, it was planned to be constructed of reinforced concrete.

The execution of this plan was commenced. The wooden gate

COLORADO RIVER,
AT LOWER MEXICAN HEADING
OF THE IMPERIAL CANAL.
SKETCH, JUNE 23d, 1905,

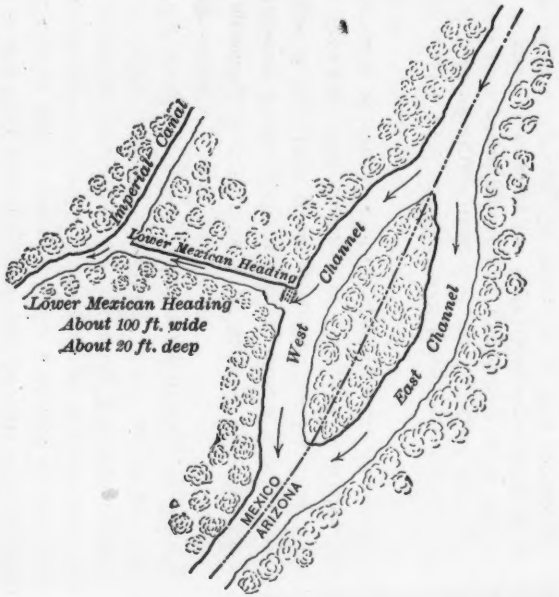


FIG. 3.

COLORADO RIVER,
AT THE LOWER MEXICAN HEADING
OF THE IMPERIAL CANAL.
SKETCH SHOWING CONDITION ON MARCH 19TH 1906

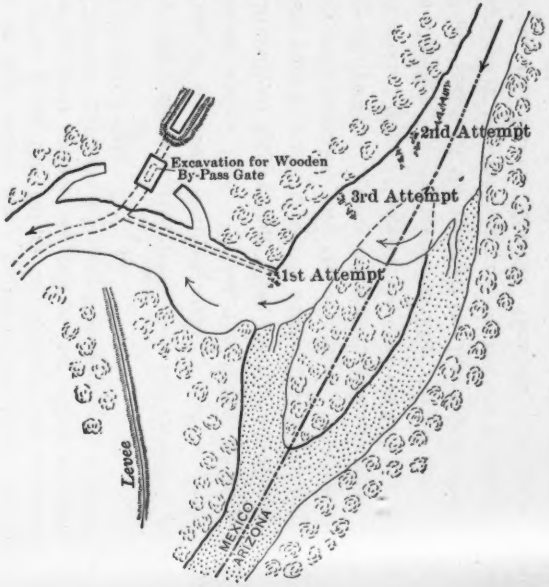


FIG. 4.

at the lower heading was constructed, but it was not ready for service as soon as had been hoped, neither did the river stages, which were too high, favor any attempt to make a closure at this point when the gate became available. The upper or concrete gate was constructed, and has been ready for use since July, 1906. Work on a canal of large capacity, beginning at the upper gate, was deferred until it should be known whether the attempt at the lower heading would succeed.

When it appeared that there was no hope of shutting off the flow into the Salton Basin in the spring of 1906, a letter was written, under date of May 10th, to the people of the Imperial Valley, by Mr. C. R. Rockwood, the Engineer in Charge, and, at that time, Assistant Manager of the California Development Company, in which he stated:

"The large wooden gate at the Lower Heading, constructed for the purpose of controlling the inflow of the Colorado through the Lower intake, is now completed and is amply able to do the work for which it is built as soon as the river falls sufficiently to allow the total flow to pass through the gates for a long enough period to construct an earthen dam across the intake. This will be when the water falls to 20 ft. on the gauge at Yuma, with a fair prospect of remaining at that height for a period of 30 days. The probability of the river doing this before the summer rise commences is so remote that, in your interest as well as that of the company, we have decided to wait until the summer flood has passed before constructing the diverting dam * * * *."

At the time this letter was written the river was already high, and kept on rising to its high summer stage, which it maintained longer than usual during 1906. In fact, throughout 1906, the river has been continually at higher stage than normal; the monthly discharge for each month is nearly if not quite equal to the maximum monthly totals ever recorded, and the aggregate discharge to date since January 1st, 1906, is already more than twice as great as the river's normal annual flow. Preparations were made for a supreme effort to stop the flow at the lower heading during the expected moderate and low stages of the river in the late fall of 1906.

A spur track about 6 miles long was constructed in August from near El Rio to the Lower Mexican Heading. A large force of men was assembled, and all the facilities at the disposal of the

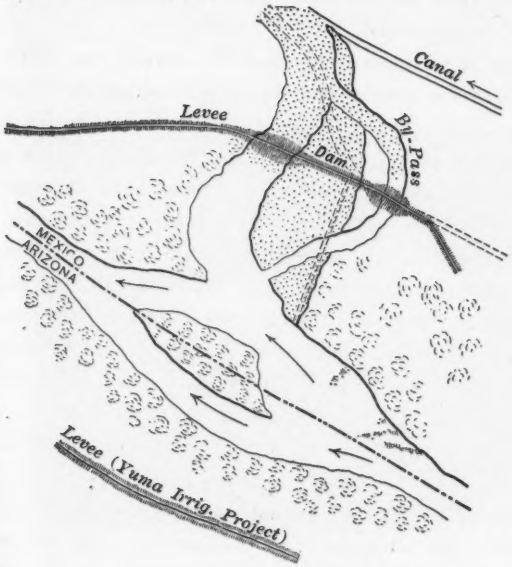


FIG. 5.

LOWER COLORADO RIVER

SKETCH ILLUSTRATING LOCATION OF DAM WHICH TURNED THE RIVER INTO ITS PROPER CHANNEL NOV. 4TH, 1906.

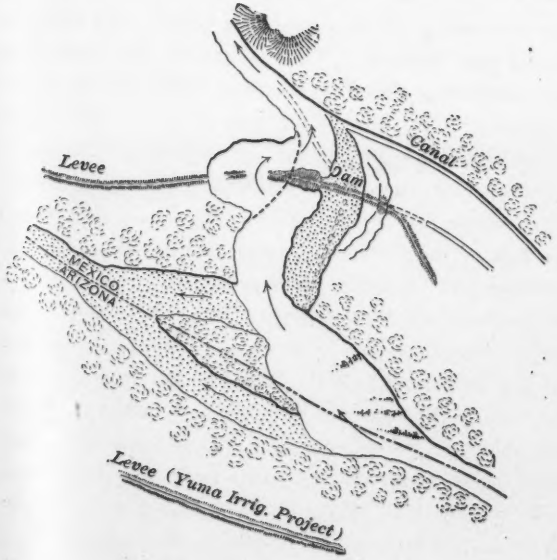


FIG. 6.

LOWER COLORADO RIVER

SKETCH SHOWING CONDITION ON DEC. 12TH, 1906.

Break in Levee occurred at 8 A.M. on Dec. 7th

railroad were called into requisition. The importance of rapid work was thoroughly appreciated.

Brush mattresses were placed successfully across the 600-ft. opening in which the river was to be held, and in which its waters were to be gradually raised by obstructing its flow with brushwork and rock. Two trestles were built across the stream, facilitating the rapid delivery of material. This work was making favorable progress, and a fair proportion of the river's flow—still far above normal—was already passing through the timber gate when, on October 11th, this gate suddenly gave way. It broke in two and its northerly half floated away. Although the situation thereupon looked hopeless, there still remained a chance of dropping rock, into the new branch of the river thus opened, faster than the water could undermine and bury it. Preparations for this work were quickly made. Orders were issued to all quarries within a radius of some 400 miles to load cars with large rock, and locomotives were pressed into service to rush the loaded cars to the work. Night and day the material thus obtained was dumped into the waterway. In the meantime the rock fill, already well advanced in the main channel of the heading, was lowered by rolling rocks from its crest, thereby increasing the flow over this barrier and reducing the flow in the by-pass channel. This operation was successful. The by-pass was completely closed on October 27th, and thereupon the dam in the main arm of the heading was raised to full height, the difficulties decreasing as the volume of flow down the river's proper channel gradually increased with the increasing height of water surface. When finally the water surface had been raised 14 ft., the entire flow of the river was in the original channel. The river was thus completely turned on November 4th.

It had been foreseen by the engineers that the deterioration of the river channel below the Lower Mexican Heading, which had occurred during the year in which the river flowed inland, would result in higher water surface elevations than had theretofore prevailed. Earth dikes or levees, therefore, were extended up and down stream from the rock dam in the canal heading. These were made 10 ft. wide on top, and had side slopes of 2 to 1. They were built of material taken from borrow-pits on the canal side.

During the last days of November and early in December heavy

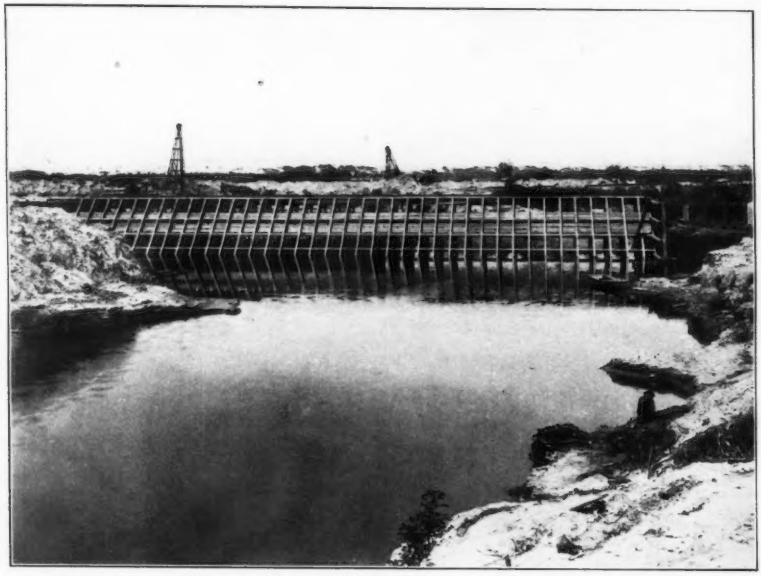


FIG. 1.—WOODEN GATE IN BY-PASS AT LOWER MEXICAN HEADING OF IMPERIAL CANAL. VIEW DOWN STREAM, AUGUST 26TH, 1906.

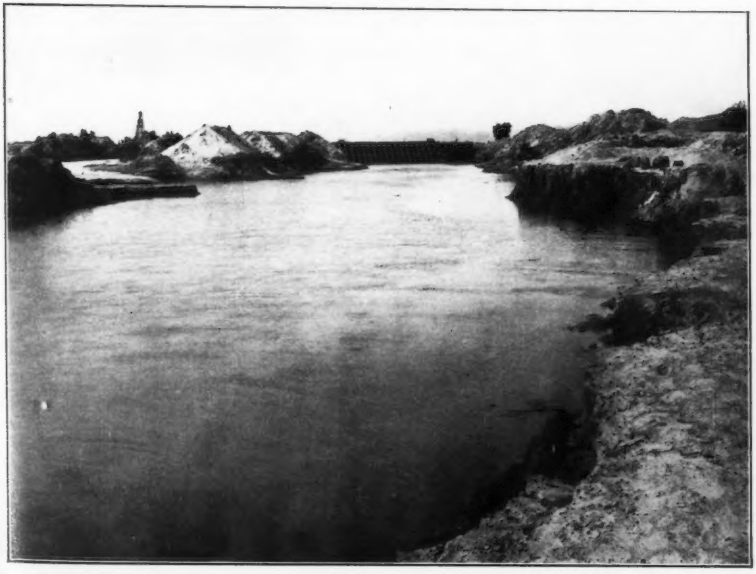


FIG. 2.—BY-PASS AT LOWER MEXICAN HEADING OF IMPERIAL CANAL, AUGUST 26TH, 1906.



rains on the headwaters of Gila River sent a freshet flow down this stream, which reached its maximum at Yuma on December 7th. The water rose to 26.2 ft. on the gauge at that point (about 7 ft. above low water), and the river's flow had been increased from about 10 000 to a maximum of 56 000 cu. ft. per sec. For points near the Lower Mexican Heading this was an overbank stage. It was found that the porous material on which the levee rested would permit considerable underflow. There was a concentration of such underflow at a point about ½ mile south of the rock dam, and the water quickly cut a passage into which the levee collapsed. This occurred early in the morning of December 7th, at a time when the water stood about 3 ft. deep against the levee. The main outflow of the percolating waters is reported to have occurred in the edge of the borrow-pit which, as already stated, was on the land side of the levee, but separated from it by a berme some 40 or 50 ft. in width.

The break in the levee rapidly widened to 800 ft. The waters flowing through concentrated in the borrow-pit, flowing north toward the canal heading, and dropped into the channel from which the river had so recently been turned. The flow along the levee could not be withstood, and soon another section, some 500 ft. in length, nearer the rock dam, was cut away. Within a few days thereafter the river had cut a channel through the yielding bank deep enough to put its entire flow back upon its inland course. The work of turning the river had to be done anew, and the magnitude of the problem of holding it when once turned, under the new complication of an inadequate levee, is now thoroughly impressed upon the engineers who have been engaged on the work or who have followed the events on the Lower Colorado.

Effects Produced by the Inland Flow of the Lower Colorado River.

The entire flow of the Colorado is again concentrated in the watercourses which lead into Salton Basin. For a time in the spring and early summer of 1906 a small quantity of water, probably never more than 4 000 out of a maximum discharge of about 90 000 cu. ft. per sec., took the course to the Gulf by way of the river's proper channel. For some months during the high

stage of 1906 there was also some flow down the Paredones, and overbank from it to the Pescadore. The aggregate quantity at any time thus reaching Hardy's Colorado, and ultimately the Gulf, by routes other than the main river was only a few thousand cubic feet per second. The remainder of the river's flow, except for the brief time that the river was turned south, went north, dropping to a plane far below sea level and traveling along lines of much steeper gradient than that of the river in a direct course to the Gulf of California.

After the flood flow of November, 1905, the Lower Mexican Heading, the canal below this point, and the Alamo River had the appearance of a continuous great river, except that for some months thereafter there was no well-defined channel through the mesquite thickets at the Lagoons. But even these thickets were broken through, the lagoons disappeared, and by August, 1906, there was a complete concentration of flow of the river, then carrying some 20 000 to 25 000 cu. ft. per sec., in one well-defined channel to within about 10 miles of Sharp's Heading where the greater part of the water took a western course through a breach in the bank of the Alamo River toward and into New River.

To illustrate the progress of the change from the river's proper course to its inland channel, it may be noted that the original lower heading, in October, 1904, had a width of from 40 to 50 ft. and a depth of from 6 to 8 ft. It had been enlarged to a width of about 100 ft. and a depth of about 20 ft. by the end of June, 1905. It had become the main channel of the river in December, 1905; was from 300 to 600 ft. wide in March, 1906, and more than ½ mile wide at some points in June, 1906. Its south bank was exposed to the violent attack of the water turned suddenly westward from a southerly course, where it left the river's proper channel, and this accounts in a measure for the rapidity with which it was cut away. Subsequent to June, 1906, during its falling stages, the river built out sand bars from the northern bank of the cut, and soon thereafter had effected the concentration of its water in a channel generally about 600 to 800 ft. wide, the south bank of which was from 3 000 to 4 000 ft. from the original north bank of the canal heading.

The large wooden by-pass gate which originally (at the begin-

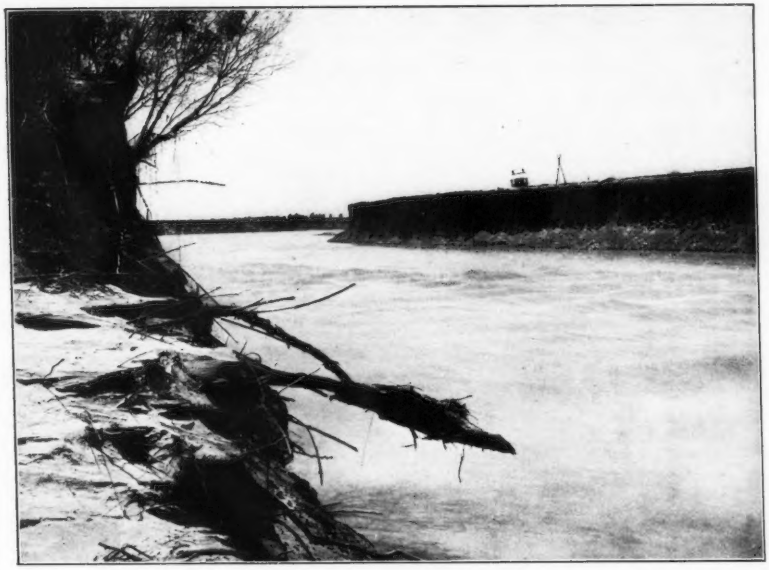


FIG. 1.—THE BARRANCA OF NEW RIVER, ABOUT 4½ MILES NORTHEAST OF BRAWLEY, AUGUST 30TH, 1906.



FIG. 2.—THE BARRANCA OF NEW RIVER, ABOUT 5 MILES NORTHWEST OF IMPERIAL, AUGUST 31ST, 1906.

ning of 1906) was within a few hundred feet (to the north) of the river's new channel was in August separated from it by broad sand bar deposits. The by-pass channel from river to gate and from gate back to river had to be made about ¾ mile long, instead of several hundred yards, as would have been the case in the early months of 1906, when the location for the gate was selected.

The immense energy of the spring flood of 1906 which poured into Salton Basin was not long in cutting great barrancas some hundreds of feet wide and from 40 to 80 ft. deep, into the alluvial soil of the Imperial Valley. The upper lip of a barranca of this kind on New River was at a point due west from Imperial on March 15th. In two months it traveled up stream some 15 miles to within a short distance of Calexico. It is reported to have progressed over portions of this distance nearly a mile in a day. Opposite Imperial, at the beginning of the year, the river was in a slight depression, practically on top of the ground, but in August it was in a chasm 80 ft. deep and upwards of 1 100 ft. in width. The sides of this barranca stand vertically, with a moderate talus at points where the water has receded from their bases. The light clay loam of which they are composed breaks away as the water makes its undercuts or softens the supporting layers. The barranca, for the present, is practically impassable. The advance of its head up stream, and the direction of its travel has been a matter of grave concern to the inhabitants of the country, and particularly to those of Calexico and Mexicali. Embankments many miles in length, during the spring of 1906, had protected the main section of the improved lands between the Alamo and New River channels from inundation, and, in like manner, dikes from 4 to 6 ft. in height and 5 miles in length, kept the water out of the main portions of these two small towns. Later, the very existence of land which had before been productive farming land and of that on which the towns stand was menaced, and much of it was devoured by the river. Efforts were made to direct the line along which the deep cut should travel. To this end dynamite was used, with some success, it is claimed. The ground was shattered above the lip of the falls, and so it was attempted to make excavation easiest along the line where the least damage would result. Here and there, however, the water tumbling over the sides as well as

the upper end of the barranca has cut long and deep gullies laterally into the adjoining country. This was notably the case when the backcutting had reached a point near the five canal gates about 4 miles north of Calexico. Here a waste-water channel concentrated the overflow waters of the easterly side, and, when the deep main barranca had reached this channel, the result was a deep lateral cut which quickly undermined a canal section and deprived Brawley and vicinity of water until a by-pass could be constructed. Again, near Calexico the cutting approached dangerously close to the town. It took some of the railroad land, all the railroad improvements at Mexicali, and many of the adobe buildings of that town, and left the remainder of these towns some 40 ft. above the plane of the river's water which, but a few days before, had covered the surrounding country 4 or 5 ft. deep and had threatened destruction by inundation. It has been estimated that from 400 000 000 to 500 000 000 cu. yd. of material have been thus excavated by the river water and "ground-sluiced" into Salton Sea.

After the high-river stage of June, 1906, the rate at which the channel cutting continued decreased materially. It is reported, however, that at this time the head of the barranca is but a few miles from the point in Mexico, some 8 or 10 miles above Sharp's Heading, where the main flow of the river leaves the Alamo through breaches in its south bank on its way across country toward New River. Should this backcutting reach the Alamo, the supply of water to the canals of the Imperial Valley will be cut off, and a water famine will quickly result.

Not only has the river been carving out the great barranca above described, but, throughout the course along which the water flows from near Pilot Knob to New River, the swirling waters have deepened the channel here and widened it there until a broad continuous channel has taken the place of the original poorly defined channels through miles of mesquite thickets. The ever-increasing capacity of this new watercourse has been continually adding to the magnitude of the problem with which the railroad people have been contending. Month by month, as channel capacity has thus increased, the river has burrowed deeper into the ground at the critical point, at the Lower Mexican Heading, and thus, as time

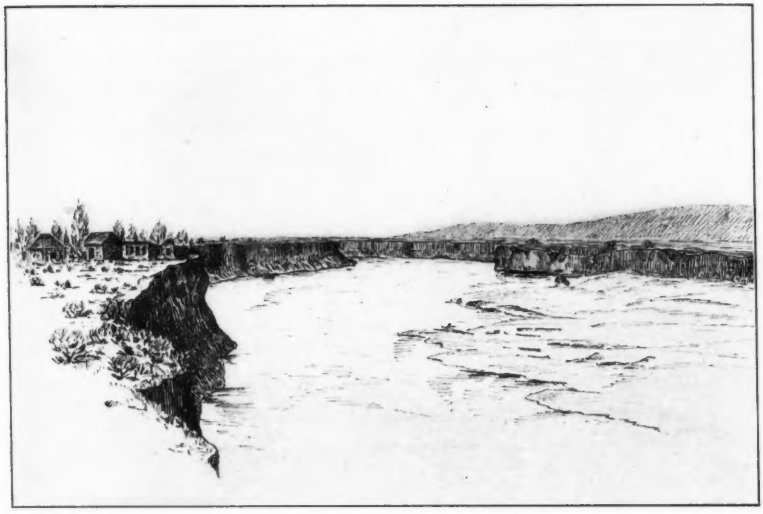


FIG. 1.—NEW RIVER, SOUTH FROM CALEXICO, AUGUST, 1906.



FIG. 2.—THE BARRANCA OF NEW RIVER AT MEXICALI, SEPTEMBER 1ST, 1906.

went on, the height that water had to be raised to send it down the proper channel increased.

At the same time there was a deterioration, in some measure, of the proper river channel below the heading. The last of the water taking that course built up sand bars for some miles down stream, and these, temporarily at least, are in the way of the restored flow. The growth of weeds and willows in the river-bed while dry is a further unwelcome obstruction.

In connection with the above-noted feature of bed enlargement and deepening, it may be stated that in the spring of 1905 the water surface was already so low in the new river channel that a waste-gate in the south canal bank, some 8 miles from the Colorado, had been left high in the air. The dredger cut toward Quail River, usually referred to as Quail River Cut, which had been made in the fall of 1905 in the hope that the river might be turned toward Volcano Lake, ceased to receive water from the Alamo channel early in August, 1906. The water was too deep in the ground to continue to flow into the head of the cut. The cutting off of the discharge of the Colorado into the Gulf was complete after August, 1906.

The Canal and Water Companies.

The land irrigated by the Imperial Canal system at the time this enterprise was undertaken was for the most part government land available for entry as desert land in tracts of 320 acres, or for entry under the homestead land law in tracts of 160 acres. In either event, the use of water was essential to reclaim the land or to make it habitable. For the Imperial Valley lands no water has been available except that from the canal system controlled by the California Development Company. All desert land entries have thus become dependent upon this company and its subsidiary companies for water supply. The total area of the land filed upon in Imperial Valley is about 250 000 acres. Approximately, 90% thereof has been filed upon as desert land.

The California Development Company has been, from the outset, and still is, in complete control of all matters relating to the water supply for the Imperial Valley. It is the parent company.

All the property necessary to be controlled in Mexico by this corporation is owned by *"La Sociedad de Irrigacion y Terrenos de la Baja California"* (*Sociedad Anonym*) which, as already stated, is presumably the same corporation as the one to which the Mexican Government made the water-right concession in 1904—*"La Sociedad de Riegos y Terrenos de la Baja California"* (*Sociedad Anonym*). The California Development Company is reported to own or control all the stock in this Mexican corporation.

The desert land law required that those who perfect title to the land entered must acquire a water right. The California Development Company did not propose to make the landowners participants in the management of its affairs, neither did it undertake to issue water rights which would run as appurtenances with individually owned tracts of land; but it arranged for the organization of a number of sub-companies, separate corporations, the stockholders in which should be landowners, and in which the stockholder was entitled to a proportional use of the water controlled by the sub-company. Eight such mutual water companies were planned, and each of the eight, it was proposed, should own and manage its own canal system, receiving water from the parent company. The capital stock of each company was fixed in relation to the area to be commanded by the sub-system of canals, so that a share of stock in any sub-company would entitle its holder to substantially the same service as a share in any other company; but the water to which ownership of stock entitles its holder must be used within the territory assigned to the sub-company issuing the stock.

The holder of stock pays for the water used at the rate of 50 cents per acre-foot, paying for at least 1 acre-foot per annum on each share of stock, whether or not any water is used.

All the stock of the sub-companies (designated by number, as Imperial Water Company No. 1, etc.) passed into the possession of the California Development Company, supposedly in payment for the canal system to be built by the parent company. The water stock thus remained under control of the parent company. One of the companies, No. 8, however, bought back its entire capital stock from the Imperial Construction Company, to which it had been transferred, substituting bonds therefor to the amount of $500 000.

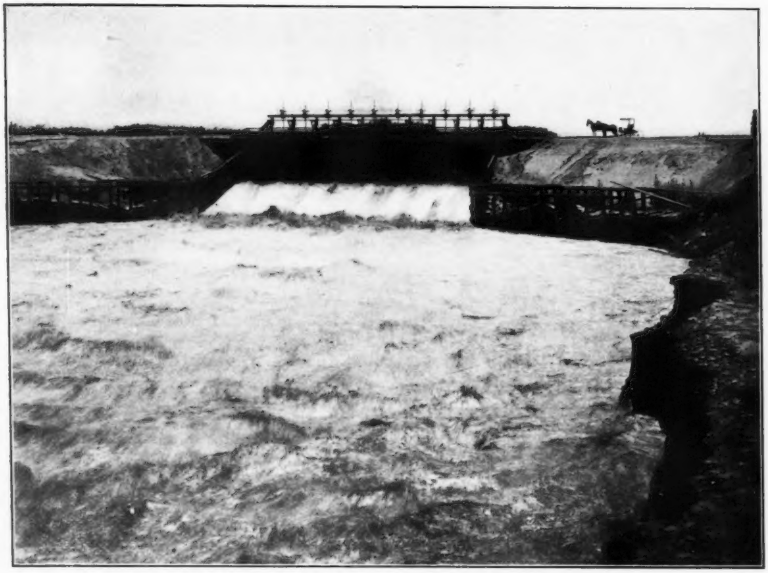


FIG. 1.—WASTE-GATE AT SHARP'S HEADING, MEXICO, ON THE ALAMO RIVER, SEPTEMBER 1ST, 1906.



FIG. 2.—WASTE-GATE AT SHARP'S HEADING, MEXICO, ON THE ALAMO RIVER, SEPTEMBER 1ST, 1906.

The relation in which the parent company stands to the mutual water companies is illustrated by the terms of an agreement made on July 24th, 1901, between the California Development Company, the Mexican Company, and Imperial Water Company No. 1, which last named is by far the most important of the several mutual companies. This agreement obligates the Mexican Company (the head of Imperial Canal No. 1 being in Mexico), upon demand of the mutual company, to furnish to the latter water as demanded not to exceed 4 acre-feet per annum for each outstanding share of stock, but conditional upon an aggregate delivery not to exceed 400 000 acre-feet per annum, and conditioned upon an annual payment of 50 cents per acre-foot.

The annual payments are to be based upon the amount of stock outstanding on the first day of June of each year, and are to be for not less than 1 acre-foot of water for each share. The price of 50 cents per acre-foot is under no circumstances to be increased. The California Development Company agrees to construct and maintain a canal, from the international boundary line to the laterals of the stockholders, of sufficient capacity to supply 4 acre-feet of water per annum for each outstanding share of stock. It also agrees to construct a system of distributing ditches for the delivery of water to a point on each quarter section of land from which it is practicable to irrigate the same by gravity flow. All ditches and laterals are to be turned over to the mutual company. The Mexican Company is to deliver 2% more water at the boundary than is required to supply the demand of the mutual company, in order to cover seepage and evaporation losses. The canal system is to be kept in good repair by the California Development Company, but this company does not hold itself responsible for failure to deliver water from any cause beyond its control. Finally, the California Development Company and the Mexican Company each guarantee the perpetual performance of all the terms and conditions of the agreement by the other. The entire control and management of the canal system, including the work in Mexico, is thus turned over to the California Development Company.

Six other mutual water companies have made similar agreements with the California Development Company and the Mexican Company.

Imperial Water Company No. 1 was organized to distribute water to 100 000 acres of land lying between Alamo and New Rivers and extending northward from the international boundary line.

Imperial Water Company No. 2 was organized for the irrigation of a small area between the same rivers, beginning 25 miles north from the international boundary line.

Imperial Water Company No. 3 was merged with No. 1.

Imperial Water Company No. 4 was organized for the irrigation of 17 500 acres lying between Districts Nos. 1 and 2.

Imperial Water Company No. 5 was organized originally for the irrigation of 100 000 acres, but this was subsequently reduced to 50 000 acres east of Alamo River, commencing at a point about 7 miles north from the international boundary line.

Imperial Water Company No. 6 was organized for the irrigation of 25 000 acres just north of the boundary line and west of New River.

Imperial Water Company No. 7 was organized for the irrigation of 20 000 acres just north of the boundary line and east of Alamo River.

Imperial Water Company No. 8 was organized for the irrigation of 40 000 acres west of New River and about opposite the territory assigned to No. 4.

The bonds, in the amount of $500 000, issued by Imperial Water Company No. 8 are 20-year bonds bearing interest at 6 per cent. The irrigators, in addition to paying 50 cents per acre-foot of water, also pay for the maintenance of the canals and for their operation.

The Imperial Land Company is another corporation affiliated with the California Development Company. It was entrusted by the latter with the sale of the stock issued by the above-mentioned mutual companies, and was paid a commission of 25% on all sales of stock.

Both this company and the Imperial Construction Company, which held the contracts for the construction of the canal systems for the several mutual water companies, were closely related to and completely controlled by the California Development Company.

When, finally, the parent company became too deeply involved

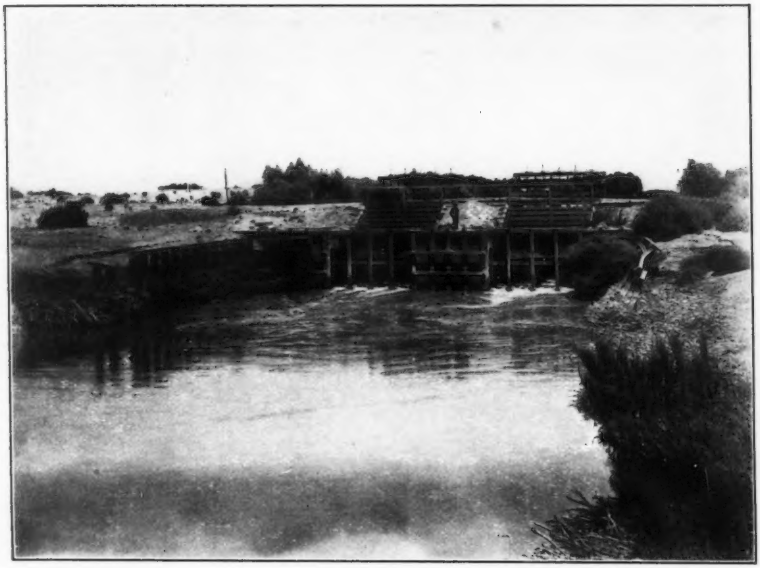


FIG. 1.—HEAD-GATE OF CANAL OF IMPERIAL WATER COMPANY NO. 1, AT SHARP'S HEADING, MEXICO, SEPTEMBER 1ST, 1906.



FIG. 2.—BRUSH MAT ON SOUTH SIDE OF LOWER MEXICAN HEADING, IMPERIAL CANAL. LOOKING NORTH, AUGUST 26TH, 1906.

financially, some of its principal stockholders organized the "Delta Investment Company," to which, it is understood, securities were sold at 50 cents on the dollar.

These matters are touched upon in order to give some idea of the involved conditions relating to the control of the water for the supply of Imperial Valley, and to show how inadequately the landowners who have bought water have been protected.

At the present time the Southern Pacific Company is, as already explained, directing the affairs of the California Development Company and of its affiliated concern, the Mexican Company, acting in this matter virtually as a trustee. The railroad company was forced into this position for its own protection. Except for energetic measures, made possible by outside financial aid, the turning of the Colorado River back into the Gulf of California by this canal company would have been hopeless from the start. With the aid of the railroad, and under the direction of its engineers, there was hope of success.

The hundreds of thousands of dollars which have been advanced to the canal companies for expenditure in Mexico were put into the work without any assurance that this money could ever be recovered. It was expended by the railroad company primarily for the protection of its own property. Whether the canal companies can ever repay it, whether Mexico can be held responsible and will make good the losses that have resulted from work done under Mexican concessions, upon Mexican territory, by a Mexican corporation, are questions which the railroad company has probably not yet considered. To stop the river first, and avert the greater calamity which was threatened, is the principle on which the railroad officials have been acting.

Development of Resources in the Imperial Valley.

Under the influence of irrigation, the Imperial country made rapid progress in all the industries common to good farming districts. The irrigated area expanded quickly to about 80 000 acres, and a much larger area was under ditch. A branch railroad, nearly 40 miles in length, was constructed by the Southern Pacific Company southward from Imperial Junction to the international boun-

dary at Calexico, and the extension of this road was well advanced into Mexico before sections of it were destroyed by New River.

It appears probable that about 275 000 acres of land in the Imperial country are suitable for irrigation. The conditions, however, are such that the system of works supplying water to this region should be absolutely reliable. The region has no auxiliary sources with which to safeguard a supply from the Colorado River. There is no soil water within reach. All water, even that for domestic use, must be brought into the country by the canal system.

Some idea of the progress which has been made in Imperial Valley is conveyed in the following statement from a letter written by Mr. W. F. Holt, President of the Imperial Water Users' Association, under date of January 17th, 1905.

"This country is practically only 3 years old, still, to-day it has about 10 000 population; it has all modern improvements, such as telephone systems, electric light plants, ice plants, water-works systems, dozens of commercial houses, railroads, good hotels, and all other things that go to make up a prosperous community. There are now in the valley over 20 000 cattle, over 30 000 hogs, and all other live stock, poultry, etc., running into thousands. The grain men estimate that the present crop will amount to over $1 000 000. There are eight public school districts in the valley to-day, employing from one to four teachers each. There are six post offices. * * * * There are two banks in the valley, both doing a large business, and two other banks are now erecting buildings. * * * The Imperial station during 1904 was the third station in amount of business done on the Southern Pacific System in Southern California, Los Angeles being the first and San Pedro the second."

Irrigation in Lower California, Mexico.

Some of the water diverted by the California Development Company from the Colorado River has been used on lands in Lower California. There has not been any subdivision of land there, nor any attempt to colonize. Irrigation has been confined to the operations of the California and Mexico Land and Cattle Company, which has had under cultivation by irrigation some 4 000 acres near Mexicali, and is prepared to extend this area rapidly to cover entirely a tract of 10 000 acres, as soon as the supply of water is sufficiently safeguarded.



FIG. 1.—DAM ACROSS LOWER MEXICAN HEADING, IMPERIAL CANAL, NEARING COMPLETION, NOVEMBER 13TH, 1906.



FIG. 2.—BY-PASS AT LOWER MEXICAN HEADING, IMPERIAL CANAL, CLOSED NOVEMBER 13TH, 1906.

The ownership of this 10 000-acre tract is apparently in the Colorado River Land Company; it was acquired, with rights to water, from the California Development Company or its affiliated Mexican corporation. The Colorado River Land Company, it is understood, now owns 450 000 acres acquired from Guillermo Andrade, and holds a lease and contract of sale to 223 560 acres more. For all this land, which has passed through the hands of Andrade, water rights in the Imperial canal are claimed, and it is asserted, moreover, that the contracts for water for this land were made with the canal company before the California Development Company had made its contracts with the mutual water companies of the Imperial Valley. It is well known that much of this land for which rights to water from the Imperial Canal are claimed is located favorably, and is otherwise well suited for irrigation.

Flow of Colorado River, and Time Required to Fill Salton Basin.

The Colorado River system drains portions of Wyoming, Utah, Colorado, and New Mexico. It has a water-shed of 225 000 sq. miles. The normal annual run-off from this area is approximately 9 000 000 acre-feet. This is distributed in the several months about as shown in Table 1.

TABLE 1.

Month.	Second-feet.	Acre-feet.
January	4 500	280 000
February	4 800	270 000
March	5 100	320 000
April	9 500	570 000
May	29 000	1 800 000
June	40 000	2 400 000
July	23 000	1 400 000
August	9 000	550 000
September	6 700	400 000
October	5 500	340 000
November	5 200	310 000
December	4 700	290 000

The gauge records prior to 1894 were not used in the preparation of Table 1, owing to the fact that the relation between water-surface elevation and discharge for earlier years has not been determined.

The flow of 1906 has not been considered in preparing Table 1. The run-off for 1906 will probably exceed that of 1905. With 1906 included in the computation, the river's normal flow at Yuma should be noted at about 10 000 000 acre-feet per annum.

It seems probable that the normal flow of the river, if estimated with the two years of excessive run-off, 1905 and 1906, included, would be entered at too high a figure. It has not seemed proper to include both these years (the latter still incomplete), in view of the fact that it is known from gauge records at Yuma since 1878 that the discharge in no other year exceeded much more than one-half of the discharge in either of these two years. The gauge records indicate that the occurrence of years of such great flow is not frequent.

The area of Salton Basin below a contour line 30 ft. above sea level is 1 947 sq. miles. As the water rises from the bed of the basin to the height of a full basin, the area of Salton Sea will increase, as follows:

For	water	surface	278	ft.	below	sea	level:	Area	0	sq.	miles.
"	"	"	253*	"	"	"	"	"	247	"	"
"	"	"	200	"	"	"	"	"	447	"	"
"	"	"	150	"	"	"	"	"	647	"	"
"	"	"	100	"	"	"	"	"	916	"	"
"	"	"	50	"	"	"	"	"	1 146	"	"
"	"	"	at sea level					"	1 753	"	"
"	"	"	30	ft.	above	seal	level:	"	1 947	"	"

The rate of evaporation from a large open water surface in the Colorado Desert has not been determined. Some experiments made at Yuma by the Agricultural Department indicate that the evaporation will be nearly 7 ft. per year from small confined bodies of water directly exposed to the full energy of the sun's rays and freely wind swept. It is believed that the evaporation from a large body of water will be less than this. Evaporation near Tulare Lake in San Joaquin Valley, is about 4 ft. per annum.† The climate there is not as continuously hot and dry during the summer as in the Colorado Desert. It is to be assumed that evaporation in the desert will be considerably in excess of that near Tulare Lake, and, in the absence of better information, it may be placed at about 6 ft. per annum effective (not allowing for rainfall, which is probably about 3 in. per annum). On this assumption, and on the further assumption that the river's annual output will be 9 000 000 acre-feet of water, it is possible to forecast what will probably be the

* Water surface on January 1st, 1906.

† Physical Data and Statistics—State Engineering Dept., California, p. 380.

stage of the Salton Sea, if the Colorado River continues to flow inland. The actual stage will vary from this forecast according to the variation of the annual discharge from the assumed normal river flow. It will rise more slowly if there be a succession of dry seasons, and more quickly if the conditions of excessive rain of the last two years continue to prevail. It will also vary from this forecast if there is material error in the assumed rate of evaporation.

Evaporation from the Salton Sea at 6 ft. per annum plus rainfall would reduce the water accession as follows:

At water surface 200 ft. below sea level, 1 700 000 acre-feet per annum.
At water surface 150 ft. below sea level, 2 500 000 acre-feet per annum.
At water surface 100 ft. below sea level, 3 500 000 acre-feet per annum.
At water surface 50 ft. below sea level, 4 400 000 acre-feet per annum.
At water surface, sea level, 6 700 000 acre-feet per annum.
At water surface, 30 ft. above sea level, 7 400 000 acre-feet per annum.

The probable annual increase in the quantity of water in the Salton Sea, therefore, will be (river discharge minus evaporation):

At water surface			200	ft.	below	sea	level,	7 300 000	acre-feet.
"	"	"	150	"	"	"	"	6 500 000	"
"	"	"	100	"	"	"	"	5 500 000	"
"	"	"	50	"	"	"	"	4 600 000	"
"	"	"	sea level,					2 300 000	"
"	"	"	30 ft. above sea level,					1 600 000	"

The water surface, therefore, must be expected to rise at the following rates per annum:

At water surface			200	ft.	below	sea	level,	25.5	ft.
"	"	"	150	"	"	"	"	15.7	"
"	"	"	100	"	"	"	"	9.4	"
"	"	"	50	"	"	"	"	6.3	"
"	"	"	sea level,					2.0	"
"	"	"	30 ft. above sea level,					1.2	"

At the close of 1906 the Salton Sea will be at an elevation of about 206 ft. below sea level. Applying the above-noted annual probable rates at which the water will rise, it will be found that the following stages of the water appear probable:

January	1st,	1907,	206	ft.	below	sea	level.
"	"	1908,	182	"	"	"	"
"	"	1909,	163	"	"	"	"
"	"	1910,	147	"	"	"	"
"	"	1912,	120	"	"	"	"
"	"	1914,	99	"	"	"	"
"	"	1916,	82	"	"	"	"
"	"	1918,	67	"	"	"	"
"	"	1920,	53	"	"	"	"
"	"	1925,	26	"	"	"	"
"	"	1930,	9	"	"	"	"
"	"	1935,	2	"	above	"	"
"	"	1940,	12	"	"	"	"
"	"	1945,	20	"	"	"	"
"	"	1950,	27	"	"	"	"

At a lake stage of 23 ft. or more above sea level, there would be some outflow through New River and Hardy's Colorado to the Gulf, and thereafter the rise to higher lake stages would be very slow.

An assumed mean annual delivery of 10 000 000 acre-feet of water into the Salton Sea would have made the following water stages appear probable:

January	1st,	1908,	179	ft.	below	sea	level.
"	"	1910,	140	"	"	"	"
"	"	1915,	80	"	"	"	"
"	"	1920,	40	"	"	"	"
"	"	1925,	14	"	"	"	"
"	"	1930,	3	"	above	"	"
"	"	1935,	16	"	"	"	"
"	"	1940,	27	"	"	"	"

EFFECT OF A PERMANENT RIVER CHANGE ON IRRIGATION POSSIBILITIES.

The seriousness of the situation on the Colorado River will appear from some additional considerations.

During all the time required to fill Salton Basin, the Colorado River will have gradients at points below Yuma exceeding those which it has long maintained with but little and very slow change while it flowed to the Gulf. The river, therefore, if the flow to the Salton Basin be not stopped, will cut its channel deeper into the ground near Yuma. Its stages will be lower there than in the past for corresponding volumes of flow.

Depression of the river channel will continue during the years that the water surface of Salton Sea remains materially below sea level; but, as the water of the sea rises to sea level and to higher elevations, there will be a corresponding rise in the bed of the river channel and a gradual restoration of channel elevations at and above Yuma to those which have been maintained so long in the past.

No prediction can be made as to the amount of channel deepening which will result from a continued flow into Salton Basin. This will depend in large measure upon the character of the material encountered as the river-bed sinks deeper below the present surface of the alluvial deposits at and above Yuma. It is quite possible that at points below Yuma, where light alluvial material to a great depth is to be assumed, the cutting will approach or even exceed 100 ft. in depth.

Whatever this deepening of channel at Yuma may be, it will be a serious matter for the lands of the river valleys all the way up stream to the river's cañon. Throughout all these valleys the water of the river may cut its channel so deep that irrigation will be out of the question, and it may swing back and forth until it cuts away most of the land of these valleys now awaiting the application of water.

The future of some 400 000 acres of land along the Colorado River is thus imperiled. It is not probable that any reasonable project can be devised for their protection or for their irrigation, if the river be not speedily turned, until the Salton Sea approaches its full stage.

If the river be not turned during the present low-water period (before the end of March, 1907), then the succeeding high stage may menace the work now being done by the United States at Laguna, some 12 miles above Yuma. The construction at that point of a

dam resting upon river silt may have to be abandoned, and all irrigation projects along the lower river may have to be modified to suit new conditions, or be entirely abandoned.

During the time that the river discharges into Salton Sea it will (as already stated) drop most of its silt at the lake margin. It will refill the great New River barranca. Progressively, as the water of the inland lake rises, it will build up its bed again, until the water stages at Yuma are again as high as they have been heretofore. When at last Salton Basin is full, the river will not only be again at and above bank heights at its high stages, but the gradients along its course inland will become less than the gradients in the direction toward the Gulf. The river will then be ready to resume its flow to the south, and the turning can probably be effected easily across the dry, barren waste which will have taken the place of the present well-watered river delta.

Operations of a Private Corporation in Mexico Caused the Temporary Inland Flow of the River.

The artificial cut in which water flows westward from the Colorado to the Imperial Canal, which has become the river channel, is located in Mexico, as already explained, 4 miles below the boundary line. It was constructed by a private canal company operating under a concession from Mexico. The work was at no time under the supervision or control of any branch of the Government of the United States. It came under the observation of officials of the Department of the Interior, who, in their work on the reclamation projects of the Lower Colorado, and their studies of the duty of water in the Imperial region, measured the stream flow at Yuma and the canal flow at a number of convenient points. As soon as the flow of the water on the Lower Mexican Heading exceeded irrigation requirements, and attempts were made to stop the flow from the river into this heading, the representatives of the Reclamation Service who had charge of this work foresaw the possible effect of a large diversion at that point, and made frequent reports on the situation. In this way the Department of the Interior has had knowledge of the operations on the river, but neither at the river nor in the Imperial Valley has it, or any other branch of the Federal Government, been connected in any way with the enterprise that

has led up to the present situation. This statement would be superfluous, except for the fact that in many sections the impression prevails that the irrigation work in the Imperial Valley had been undertaken or taken over by the Reclamation Service.

It should be noted that a proposition to assist the Imperial Valley was under consideration by the Reclamation Service in 1904. At that time a Water Users' Association had been formed, and, after negotiations with the owners of the Imperial Canal System, this Association urged upon the Reclamation Service the purchase of the properties of the California Development Company with certain exceptions, for the sum of $3 000 000. This price was considered too high. This and other circumstances, notably the complications resulting from the necessity of carrying water through Mexico, made it impracticable for the Reclamation Service to come to the aid of the settlers.

Colorado River as an International Boundary. The River's Navigability.

The Colorado River, beginning at a point about 8 miles below Yuma, where the boundary line between California and Lower California leaves the river, is the boundary between the United States and Mexico for a distance of about 20 miles. The position of this part of the international boundary is defined as the middle of the stream. The navigability of this part of the river was apparently recognized in the treaties of Mexico relating to the international boundary. According to the provisions of the treaty of Guadalupe Hidalgo (1848), neither country is to permit works throughout the portion of the river which is common boundary which would interfere with the navigability of the river. The treaty of 1853 cancels this provision, but guarantees to the United States the free and uninterrupted passage of vessels and citizens so far as the river forms the common boundary between the two countries.

There has been practically no commerce on the river below Yuma since the completion of the Southern Pacific Railroad in 1877; and there has been no expenditure by the War Department for its improvement. The result of a preliminary examination of the Colorado River from Yuma to the Mexican boundary line is reported as

follows by General G. L. Gillespie, Chief of Engineers, under date of December 1st, 1903:

"In the opinion of Captain Jadwin, the Division Engineer, Lieut.-Col. D. P. Heap, Corps of Engineers, and the Board of Engineers for Rivers and Harbors, which has reviewed this report, in pursuance of Sections 3 and 14 of the above mentioned act, the locality is not worthy of improvement by the United States."

Referring to the situation at the Lower Mexican Heading, Col. W. H. Heuer, Engineer Corps, U. S. Army, under date of September 13th, 1905, reported:

"Under these circumstances it would seem that the costs of investigation, plans, estimates and work of closing or controlling the outlets, if such should be required, should be borne not by the War Department, but by others whose interests involved are incomparably greater."

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MOVABLE BRIDGES.

By C. C. Schneider, Past-President, Am. Soc. C. E.

To be Presented April 3d, 1907.

The subject of this paper is a review of the mechanical features of movable bridges, and a set of specifications covering their operating machinery or kinetic parts, which the writer respectfully submits for discussion and criticism. The specifications contain the writer's views as to construction and workmanship, also the principles he has followed for his own guide and practice in designing movable bridges. To his knowledge, no specifications of this kind have been published, up to the present time. He hopes that this paper will bring out a full discussion from those who have had experience with movable bridges and other mechanical work covered by his specifications.

A movable bridge is one which may be turned or drawn to one side, lifted up, or let down, so as to permit vessels to pass in the stream which it spans.

Movable bridges may be classified as follows:

1.—Swing bridges, turning about a vertical axis;

2.—Bascule bridges, turning about a horizontal axis, or rolling back on a circular segment;

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

3.—Traversing or retractile bridges, moving horizontally;
4.—Lift bridges, lifting vertically;
5.—Transporter or ferry bridges, consisting of a fixed span with suspended traveler.

As belonging to the movable bridges, may also be mentioned the pontoon or floating swing bridge. As it is hardly likely that this type of bridge will be much used in America, it will not be considered in this paper.

1.—Swing Bridges.

The swing bridge consists of the superstructure attached to and turning around a pivot, and provided with some means whereby, when closed, the deflection of the girders may be taken out and the ends supported at the proper level. The pivot may be in the center of the span, forming a truss of two equal arms which balance each other and give two openings for navigation; or it may be at one side of the center, forming a truss with unequal arms, in which case the short arm is counterweighted to balance the bridge about its pivot. They may be single or double; in the latter case, they will have to be provided with a locking arrangement at the center where the arms meet, while the shore ends will have to be held down or anchored to the masonry when the bridge is closed, acting as cantilevers. Swing bridges are divided into three classes: Center-bearing, rim-bearing, and a combination of the two.

The Center-Bearing Bridge.—This bridge, while swinging, is carried entirely on the center pivot. The trailing wheels, which roll on a track near the outer edge of the pier, are not assumed to carry any load, but are used to balance the bridge and insure lateral stability while swinging. In short, light, highway spans the portion of the live load which comes on the center when the bridge is closed is sometimes also carried by the pivot. In more important highway bridges, and in all railroad bridges however built at the present time, the live load at the center is carried on wedges or other independent supports on the pivot pier. In some cases center-bearing bridges of small spans are supported and balanced by the center pivot while swinging—dispensing with balance wheels. They are generally lifted bodily at the center by hydraulic pressure to clear the end bearings.

The Rim-Bearing Bridge.—This bridge, while swinging, is carried by a circular girder or drum on a concentric ring of conical rollers which roll on a corresponding roller path or track; the center pivot receives no load. The rollers also carry the live load at the pivot pier when the bridge is closed.

The less important types of swing bridges are: The shear-pole draw and the jack-knife draw.

The Shear-Pole Draw.—This bridge has only one leaf turning around a pivot at one end; the other end, while swinging, is suspended from the top of a two-legged shear-pole by rods which are attached to a pivot which is vertically in the same line as the pivot below. The shear-pole is stayed by guy rods from the shore end. When the bridge is closed it forms a simple span supported at both ends.

The Jack-Knife or Folding Draw.—This bridge differs from the shear-pole draw in that it consists of two or more separate trusses or girders, each girder swinging horizontally around its own pivot at one end. The other end, while swinging, is suspended from a frame or tower by rods attached to pivots on top of the frame. The rails are fastened to the top of each girder; there are no ties. The girders are connected with hinged links, and fold up close to each other when the bridge is fully opened. When the bridge is closed one end of each girder rests on the shoe at the abutment while the other end rests on the pivot. This type of bridge can only be used for railroad traffic.

2.—Bascule Bridges.

This type has been productive of a greater variety of designs than any other kind of movable bridge. Some are designed to rotate about trunnions at one end, the other end being lifted by hoisting ropes from a tower; some are turned by gearing on a segment; some roll back on circular segments, and others have a combined motion of turning and rolling. Nearly all the mechanical motions and devices have been used in designing operating mechanisms and machinery for bascule bridges. The various patented designs offered are so numerous and of such variety as to preclude their mention. Bascule bridges are made in one leaf, or in two leaves which meet in the center. The two-leaf bridges have a locking device at the ends, and are arranged to act as cantilevers when closed, and

sometimes as three-hinged arches. All bascule bridges are counterweighted to reduce the power required for operation. Some very ingenious arrangements of counterweighting have been devised to balance the weight of the span in all stages and positions during opening and closing. The writer hopes that those who have meritorious designs to offer will submit them and point out their advantages, in the discussion of this paper.

3.—Traversing or Retractile Bridges.

Traversing or retractile bridges consist of a simple span across an opening, extended some distance on one side over the abutment. This portion is supported on wheels, and is counterweighted, the overhanging portion acting as a cantilever when the bridge is moving, and resting on the opposite abutment when closed. Traversing bridges are constructed so as to be capable of being rolled horizontally backward in the direction of the center line, or transversely to the center line of the bridge. In the latter case the bridge generally crosses the opening on a skew. In some cases the bridge rolls transversely upon its carriage until it has passed and cleared the track, and then rolls backward to clear the waterway.

4.—Lift Bridges.

A lift bridge consists of a simple span resting on abutments when closed. To the ends of the girders are attached ropes or chains which pass over sheaves on top of a frame at each end of the bridge, by which the vertical motion is accomplished. They are counterbalanced to reduce the power required for lifting.

5.—Transporter or Ferry Bridges.

This type consists of an elevated fixed span supported on towers on each side of the stream. From this fixed span is suspended a platform or car which travels across the opening and thus conveys the traffic from shore to shore. The elevation of the fixed span is such as to clear navigation. The first bridges of this kind were of the suspension type, with a car suspended by wire rope. The only example of this type in America is the ferry bridge across the ship canal at Duluth, Minn., of about 390 ft. clear span. For the fixed span, riveted steel trusses are used, and the car or traveler suspension is of a substantial riveted construction.

Selection of Design.

It is impossible to lay down any hard and fast rule as to which kind of bridge is best adapted for a certain location and under certain conditions; there are so many factors entering into the problem that even the experienced designer is often at a loss to decide on the proper kind of structure.

The writer, in his own practice, has always observed the following fundamental principles in selecting a design for any kind of movable bridge:

1.—When the bridge is closed, and ready to carry traffic, it should be as nearly as possible a fixed span, complying with the requirements of good practice for a permanent structure.

2.—The operating machinery should be designed so that the bridge can be easily handled and operated while moving. The most simple design which gives the least frictional resistance, and also the least first cost and cost of subsequent operation and maintenance, should receive the preference.

3.—The structural and machinery parts of the bridge should be separate and distinct. That is, when the bridge is closed, acting as a fixed span, the machinery parts should receive no strain; and only when the bridge is moving should the machinery parts be in service.

When there are no restricting conditions, a swing bridge is generally the most satisfactory. It is best adapted for long spans; and, for spanning two equal openings, it is the most economical and simple of any. Swing bridges have been built for single- and double- track railroad structures up to 520 ft. span, and for four-track structures up to 390 ft. span, and may be used for spans of much greater length. If there are no other restricting conditions, a swing bridge with equal arms should be selected. If the conditions are such that the pivot pier has to be located at or near the shore, with limited room back of the shore end, a bridge of unequal arms will be best adapted, provided space is available for swinging the bridge.

As stated before, the usual types are center-bearing and rim-bearing swing bridges. The center-bearing type, designed in accord-

ance with good modern practice, offers more advantages than the rim-bearing type, and should always receive the first consideration in determining upon a design. It requires less power to turn, has a smaller number of moving parts, is less expensive to construct and maintain, requires less accurate construction than the rim-bearing bridge, and does not as easily get out of order. The structural and the operating or machinery parts are entirely separate, and when the bridge is closed it forms either two independent fixed spans, or a fixed span continuous over two openings resting on firm, substantial supports. There are no ambiguities in the calculations, in reference to the distribution of the load, and the distance required from base of rail to masonry is generally less than that required for a rim-bearing bridge with proper distribution of the load over the drum. Any irregular settlement of the masonry does not materially affect its operation.

On the other hand, the rim-bearing bridge requires a circular girder or drum of difficult and expensive construction, a ring of accurately-turned rollers, and circular tracks, which require great care in their construction and delicate adjustment in their erection in order to make the bridge operate satisfactorily. Repairs are troublesome and expensive, and any irregular settlement of the masonry will throw the whole turning apparatus out of order.

The only limit to the center-bearing type is generally the width of the bridge. As the entire weight of the bridge while swinging is carried on the cross-girders to the center pivot, these girders—if the width is excessive—may become so long, and the weight they have to carry so great, as to make their construction impracticable. Center-bearing bridges are adapted for single-track structures of any span, and for double-track they have proven satisfactory up to 323 ft. total span. The writer has also used the center-bearing type for a three-track bridge of 200 ft. total span. For four-track bridges of long span, and for heavy highway bridges carrying wide city streets, the center-bearing type is not as well adapted.

In the center-bearing swing bridge of the modern type of construction, the entire load while swinging is carried on the pivot; the trailing wheels are adjusted so as to have a little clearance. When the bridge is closed, the trusses at the center are borne on wedges or other substantial supports. These supports are not sup-

posed to lift, but should only come in contact; they carry practically all the live load. The center supports and end lifts should be connected so as to work simultaneously, and adjusted so that, when the center supports come to a bearing, the ends are lifted to their proper level. For the center supports the writer uses wedges with a bevel of 1 to 10. The trailing wheels he has used in connection with this type of bridge are from 15 to 20 in. in diameter and from 4 to 6 in. in tread. He generally uses eight wheels, two on each side of the center line of the floor system to balance the bridge transversely, and two pairs at right angles to them to balance the bridge longitudinally, while swinging. It is his practice to proportion the diameter, width of tread, size of axles, and journals of the wheels on each side of the track for an overturning wind pressure of 20 lb. per sq. ft. while swinging, and make the other wheels duplicates of the same.

There are two methods of carrying the weight on the center pivot of a swing bridge: by suspension or by superposition. The advantages of the suspension method are that it brings the point of support nearer the center of gravity of the bridge, that the disks or rollers can be readily taken out, examined, or replaced without stopping the traffic over the bridge, and, also, that it affords an easy means of adjusting the height. Several kinds of pivots have been used for swing bridges: with disks, conical rollers and balls. In the writer's experience, disks have given the best results. Conical rollers have proven unsatisfactory, and have given more or less trouble in many cases where they have been used. As the frictional resistance in rollers is approximately the same as in disks, the pivot with conical rollers has no advantages, and, therefore, is not to be recommended. The best results have been obtained with a phosphor-bronze disk between two hardened-steel disks. As the surfaces of the hardened-steel disks in contact with phosphor-bronze will not wear out, the wearing is confined to the phosphor-bronze disk, which is, therefore, practically the only part outside of the operating machinery which will in time wear out and have to be replaced.

Ball bearings have been used in some cases, and it is claimed that they have proven satisfactory on account of the great reduction of friction. The writer has not been able to obtain any reliable data on this subject.

If the conditions are such as to make a center-bearing swing bridge impracticable, the rim-bearing type has to be used.

The most important requirement for a satisfactory rim-bearing swing bridge is to have the load equally distributed over all the rollers. If this is not accomplished, some rollers will receive more load than others, the drum with the upper track will deflect between the points of support, and the bridge will turn hard, and, consequently, there will be a great deal of unnecessary wear and tear on the rollers and track. In order to obtain an equal distribution, it is necessary to have practically no deflection in the drum between the points of support. To effect this, the points of support should be close together and the depth of the drum relatively great. In the writer's judgment, the depth of the drum should be not much smaller than one-half, in no case less than four-tenths of the distance between the centers of support. Many rim-bearing swing bridges for single-track have been built with only four points of support on the drum. This is inadequate for good distribution; they should have at least eight points, and double-track bridges preferably more. The distribution should be precise, and should be arranged so that it will not be affected by the deflection of the distributing girders.

Rim-bearing swing bridges in some cases give trouble on account of the center pivot working loose, as a result of inaccurate workmanship or adjustment, or by bad masonry. For this reason, it is an advantage to have a certain portion of the weight on the pivot while the bridge is swinging, as it assists in resisting any tendency toward lateral movement on the part of the ring of live rollers. If this is done, the arrangement of distribution should be such that the portion of the load which is to be carried by the pivot can be determined accurately. The usual practice in such cases is to carry about one-fifth or less of the entire dead load on the center pivot while the bridge is swinging.

In case it is impracticable to carry a portion of the load on the pivot, the lower circular track should be connected to the pivot with radial struts so that the track and pivot form one piece which can be fitted together and centered accurately in the shop. In order to prevent the center pivot from working loose, some engineers have embedded its base in concrete. This method may keep the pivot in

position, but it does not prevent the pushing, pulling and wearing around the collar of the pivot.

The live-ring arrangement for separating and holding the rollers —which was formerly popular—consisting of adjustable radial rods, one end of each rod carrying a roller, the other end being connected to a ring revolving around the center pivot, is, to say the least, an unmechanical contrivance. Good practice requires a more substantial construction. The rollers should run between two concentric circular girders firmly connected to each other; this ring should be connected to the revolving part of the pivot by rigid struts.

End Lift.—All swing bridges require an arrangement to lift the ends when closed, so as to make the span continuous over three or four supports, or to make two separate simple spans. Various mechanical contrivances are used for this purpose, such as rollers, screws, cams, eccentrics, toggle joints, wedges, hydraulic rams, etc. In the writer's opinion, the lifting apparatus should fulfill the following requirements:

1.—The end lift should have power enough to lift the ends to the desired level with nearly uniform resistance.

2.—After the ends are lifted to their final position, they should form solid, substantial supports, similar to the end shoes of a fixed span.

That kind of end lift which supports the ends of the bridge, when closed, on rollers, toggle joints, or links, is not to be recommended. The writer has found wedges with a bevel of 1 to 5 or 1 to 6 the most satisfactory. The mechanism for moving the wedges can be arranged so as to offer nearly uniform resistance in all stages of the lifting, and also to lock the wedges to prevent them from sliding backward. They form as substantial supports for the ends under traffic as can be desired. Toggle joints and hydraulic rams have also proven satisfactory, if supplemented by wedges or other substantial supports, after the lifting is accomplished.

In center-bearing bridges of moderate span, with unequal arms, especially when the short arm is over the abutment, it is of advantage to have the lifting apparatus only under one end. This end should have an excess of weight, so that, when the end supports are removed, the bridge will tilt and throw some weight

on the balance wheels. The opposite ends of the girders simply rest on bed-plates. This arrangement dispenses with one-half of the lifting machinery.

Such tilting arrangements may also be used in case the lifting is done in the center by a hydraulic ram under the pivot.

Some swing bridges are designed with sufficient lift at the ends to make the trusses discontinuous, so that they will form two separate simple spans when the bridge is closed. The operation of this requires approximately ten times as much work as if the ends were lifted only enough to prevent the lifting of the ends from their supports under traffic and their consequent hammering. This arrangement, therefore, is a disadvantage in a bridge which has to be opened and closed frequently and quickly; in fact, it is only a waste of power, but may be recommended in cases where the bridge is used almost entirely as a fixed span, and where the time required for the opening is of no importance. Lifting the bridge from the center is not as economical as lifting at the ends, on account of the greater power required. A few bridges have been built with a lifting apparatus applied at the top chord of the center panel. This arrangement has the additional disadvantage of using a part of the structure which carries the strain while the bridge is swinging also as a part of the lifting mechanism, which is not good practice. If the machinery parts get out of order, the structure should not be affected thereby. The writer's experience with a structure of this kind prompts him to advise against its use.

The Shear-Pole Draw, and the Jack-Knife Draw.—These also come under the head of swing bridges, but can only be used for very small spans. They are not to be recommended, except as temporary makeshifts on new roads, or in places where there is little navigation.

Bascule Bridges.—If the conditions are not favorable for a swing span, a bascule bridge is the next choice. The conditions which preclude the use of a swing bridge are:

If there is no space available to swing the bridge horizontally about its vertical axis;

If the number of tracks is such as to increase the width of the bridge and the size of the pivot pier to such an extent as to make it undesirable or impracticable; or,

If there is a probability that other tracks will have to be added in the future.

The turning space required for swing bridges is a disadvantage, and increases with the size of the bridge. The bascule bridge, on the other hand, has the advantage that it can be used in places where there is no space available alongside of the bridge. The bascule bridge can be enlarged or widened by putting up additional spans alongside of it, without interfering with the operations of the existing span or with navigation. The length of span, however, is somewhat limited, as the question of wind pressure becomes very important in long spans, and constitutes one of its greatest disadvantages.

The limiting length of clear span is probably 150 ft. for single-leaf, and 300 ft. for double-leaf bridges.

The design which should be selected for a bascule bridge depends upon many conditions, such as location, distance from the floor to water level, under-clearance required, length of span, frequency of opening, speed required, kind of power available for operating, etc. In determining the type and details of the design which will be most suitable for the existing conditions, the principles mentioned before, which govern all kinds of movable bridges, should be considered.

Traversing or Retractile Bridges.—There are some objections to the traversing bridge, which make it undesirable, especially for railroad traffic. It requires more power to move it than almost any other kind of movable bridge, and is slow of motion. It has been used in only a few cases for railroad bridges, but has proved satisfactory for small highway bridges. It has been used successfully in some locations where no other type would answer, as it fits certain conditions better than any other design.

Vertical-Lift Bridges.—The vertical-lift bridge has the following advantages over the bascule bridge:

It can be made of any length feasible for a simple span, while the span of a bascule bridge is somewhat limited. The bridge, when closed and carrying the traffic, forms a simple fixed span, fulfilling all the requirements of a permanent structure. Its disadvantages are heavy first cost and maintenance, and expensive

operation. The vertical-lift bridge is most suitable for spans which require only a small lift, such as bridges over canals.

Transporter or Ferry Bridges.—Such bridges take the place of ferries. They have the advantage over the ferry-boat that their operations are not obstructed by ice; therefore they can be used in cold climates all the year round, where the operation of ferries would have to be discontinued during the winter months. Their capacity, however, is very limited, and they are not suitable for railroad uses.

Power Required to Operate Movable Bridges.

The determination of the power required to operate movable bridges is not a matter of elaborate scientific calculation, but of practical experience and judgment. One should be guided in a general way, of course, by the experiments which have been made to ascertain the frictional resistance in different kinds of movable bridges; but, as the conditions do not remain the same, the frictional resistance varying in different bridges even of the same type and construction, and as the machinery sometimes rusts up, a wide margin for the required power should be allowed. It is always an advantage to have an excess of power, as it adds only a very small percentage to the total cost of the structure, does not increase the operating expenses, and increases the efficiency and reliability of the operating machinery.

The resistances to be overcome in turning a swing bridge are:

1.—Resistance due to friction;
2.—Resistance due to the inertia of the bridge;
3.—Resistance due to the action of the wind.

1.—Resistance Due to Friction.—For rim-bearing swing bridges, the late C. Shaler Smith, M. Am. Soc. C. E., found the total frictional resistance in the live ring to vary from 0.004 to 0.008 of the load on the rollers. Messrs. Boller and Schumacher found this coefficient to be 0.0035 for the Thames River Bridge; and Theodore Cooper, M. Am. Soc. C. E., found this to be 0.0038 for the Second Avenue Bridge. For center-bearing bridges, Mr. C. Shaler Smith found the frictional resistance at the circumference of the pivot to be 0.09 of the weight turned. The writer found the coefficient

of fractional resistance at the circumference of the pivot, on hardened-steel and phosphor-bronze disks, with the usual working pressure of about 3 000 lb. per sq. in., to be 0.067 at the start, and 0.045 to keep the bridge moving at a uniform speed. For the total frictional resistance, including that of the shafts and gearing required for hand-operation, the highest coefficients observed were 0.115 for starting and 0.08 for keeping the bridge in motion. These experiments were made on new bridges, before the gearing, etc., had an opportunity to wear smooth. For bridges which have been in operation for some time, these coefficients would be found to be considerably smaller.

2.—Resistance Due to the Inertia of the Bridge.—The power required to overcome the inertia of the swinging mass and develop the desired velocity depends upon the time allowed for opening or closing. It is the usual practice to assume that the acceleration is developed in half the time it takes to open the bridge. With this assumption, the following approximate formulas will give results near enough for practical purposes:

$$P = \frac{W \rho}{20.5\ t^2};$$

$$H\text{-}P = \frac{P\ v}{550} = \frac{W \rho^2}{7\ 170\ t^3};$$

P = Force applied to the center of gyration necessary to produce the required acceleration;

H-P = Number of horse-powers;

W = Total moving weight, in pounds;

l = Length of bridge;

b = Width of bridge;

ρ = Radius of gyration $= \sqrt{\frac{b^2 + l^2}{12}}$, approximately $0.29\ l$;

t = Time, in seconds, in which maximum velocity must be obtained, or one-half the number of seconds required to open the bridge;

v = Maximum linear velocity at the center of gyration, in feet per second $= \frac{\pi \rho}{2\ t}$.

3.—Resistance Due to the Action of the Wind.—Some engineers assume an unbalanced wind pressure of 4 or 5 lb. per sq. ft. in de-

termining the power required to overcome the resistance caused by the wind. This unbalanced wind pressure is considered to act entirely on one arm of the bridge at right angles, and follow the bridge in its various positions while swinging. This is an arbitrary assumption which has never been verified. It is known, however, from actual observation, that with a strong wind it may require nearly twice the power to turn the bridge than without wind. It is suggested, therefore, that the resistance due to the action of the wind be included in the coefficient of friction.

This, of course, applies only to swing bridges with two equal arms. If the bridge has arms of unequal length, the resistance due to wind pressure should be calculated and included in the total resistance.

For rim-bearing bridges, the writer's practice has been to assume as the total resistance to be overcome in turning, including frictional resistance of the gearing and wind pressure, about twice the value given by Mr. C. Shaler Smith for frictional resistance, which value was also recommended later by Messrs. Boller and Schumacher, *viz.*, 0.015 of the load on the rollers acting in the center line of the track; and, for center-bearing bridges, 0.15 of the load on the pivot, when swinging, acting on the circumference of the pivot. In estimating the capacity of the motor, he assumes a linear velocity, in the center line of the track, of twice that required for turning the bridge in the specified time; or, as expressed by formulas:

$P = 0.015$, for rim-bearing;

$P = 0.15\ W \frac{r}{R}$, for center-bearing;

$$H\text{-}P = \frac{P\,v}{550};$$

$$v = \frac{R\,\pi}{2\,t};$$

P = Force required to turn the bridge, acting in center line of track;

W = Total moving weight, in pounds;

H-P = Number of horse-powers;

r = Radius of pivot;

R = Radius of center line of track;

v = Maximum linear velocity in center line of track, in feet per second;

t = Time, in seconds, in which maximum velocity must be obtained, or one-half the number of seconds required to open the bridge.

The foregoing formulas for frictional resistance generally give results in excess of the power actually needed under ordinary conditions, and practically cover all contingencies.

It is supposed, of course, that the bridges are of rational construction and average workmanship.

If the bridge is to be operated by hand-power, the gearing has to be arranged, either for the number of men available, or for the time required to turn and operate the bridge. Mr. C. Shaler Smith recommended the assumption of the power of one man on a capstan bar with 40 lb. at a speed of 250 ft. per min. The writer found that this velocity is somewhat high, and does not fit all sizes of men, but that the work which can be performed conveniently by any ordinary man for considerable time is about 40 lb. with a speed of 160 ft. per min. In calculating the strength of the gearing, etc., the power of one man should be taken at 125 lb., as this is about the force a strong man, with a foothold, can exert for a short time.

For bascule and lift bridges the writer has not been able to obtain any data in reference to frictional resistance and power required for operating, but experiments may have been made, and he hopes that their results will be brought out in the discussion of this paper.

In bascule and lift bridges, the wind pressure is an important factor in increasing the frictional resistance of the machinery, but the pressure may be taken as much smaller than that usually specified for the structural parts of the bridge, as navigation would be impossible with such a wind, so that the bridge would not require to be opened. The writer believes that 20 lb. per sq. ft., corresponding to a velocity of about 60 miles per hour, is sufficient for all cases.

For swing bridges, it has been the usual practice to use a foot-brake to control or stop the motion of the bridge. This, no doubt,

is a good precaution, where it can be conveniently arranged, as in cases where the motor is located in the operator's house. However, when the bridge is operated by electricity, the motors on the shafts of the operating machinery are not generally within reach of the operator, and the introduction of a foot-brake involves considerable complication. For this reason, the writer has omitted brakes in all swing bridges operated by electricity, and this has proved satisfactory in all cases.

Motors.

In the past, up to about fifteen years ago, steam and hydraulic power were the only motive powers used for operating movable bridges. In later years, electric and internal combustion motors have in many cases taken the place of the steam engine.

Electric motors are the most convenient, where electric power can be obtained satisfactorily, more particularly if the company owning the bridge also controls the power, such as is the case with electric railway bridges, or steam railroad bridges situated near one of the company's power-houses, or city bridges. Electric power is economical, and the motors occupy little space and can be put in the most convenient places, so as to reduce the transmission by long shafts.

The requirements for electric motors and electrical equipment given in the subjoined specifications are based on those adopted by the Sanitary District of Chicago for their bridge crossing the Chicago River at Dearborn Street, which appeared to be the most complete of any which have come to the writer's notice. They have been modified so as to make them general, and applicable to any kind of movable bridge.

Where electric power cannot be obtained, a steam engine or internal combustion engine has to be used, excepting in special cases, where water-power may be used to advantage. For large spans, which have to be opened frequently and quickly, a steam engine is preferable. However, it has its disadvantages. It occupies more room than almost any other motor, as it requires storage capacity for coal and water, machinery for hoisting coal and pumping water, and the ashes have to be disposed of. The

fire has to be kept up in the boiler when the bridge is not in operation, and the operating expenses are high.

For smaller spans and intermittent service, the gasoline engine is better adapted. It is more economical, and requires less skill to operate than the steam engine. The internal combustion engine has been brought to a high degree of development, particularly in the smaller sizes, and many of the defects of the earlier engines are now almost eliminated. Gasoline engines, up to 50 h. p., have been used successfully for operating movable bridges.

So many different types of gasoline and other internal combustion motors have come into the market in the last few years, such as vertical and horizontal engines, engines with one, two and three cylinders, two-cycle and four-cycle motors, etc., that engineers who are not experts in internal combustion engines are generally puzzled when called upon to select the most suitable engine for the work to be performed in operating a movable bridge. The writer hopes that this subject will be discussed by engineers familiar with the latest developments in these engines.

Hydraulic power can be used to advantage in exceptional cases only, where the bridge is operated from the shore, and where water with sufficient pressure can be obtained for working a hydraulic motor.

Hydraulic power, however, is generally used with hydraulic rams in connection with accumulators. They have the advantage that a great amount of power can be accumulated with a small motor during the time the bridge is not being operated. Arrangements of this kind have been used successfully on a number of bridges.

Unit Strains.

The permissible unit strains for machinery parts in tension, compression, bending and torsion, given in the subjoined specifications, are those recommended by Professors Von Bach and Unwin, slightly modified to conform to the writer's views. The safe bearing values given for rotating and sliding surfaces agree with those now generally considered good practice in machine design, and have been used extensively and verified by the writer.

The safe bearing pressures on rollers are based on experiments made by James Christie, M. Am. Soc. C. E.

The values of the permissible pressure on ball bearings of hardened steel are those recommended by R. Stribeck as the result of his experiments, made at the Prussian Government Laboratory, on balls and races manufactured abroad. These values, therefore, are not applicable to ball bearings manufactured in the United States, about which the writer was not able to obtain any information.

Workmanship and Material.

The quality of workmanship called for in the specifications is the same as the writer has required for machinery parts of movable bridges, when he has had control of the shops where the work was being done.

The specifications for special metals, generally not covered by specifications for the structural work of bridges, are practically those adopted by the American Society for Testing Materials. For tool steel, phosphor-bronze and babbitt metal, for which that society has no specifications, the writer has given what he has found satisfactory in his own practice.

SPECIFICATIONS FOR MOVABLE BRIDGES.

Types of Bridges.

Movable bridges, of the kind used in modern practice for carrying railroad traffic, are generally of the following types:

1.—Swing Bridges;
2.—Bascule Bridges;
3.—Vertical Lift Bridges.

The type of bridge best adapted for a particular location depends upon local conditions, and should be left to the judgment of the engineer.

Loads, Unit Strains, etc.

The specifications for loads, unit strains, proportion of parts, material and workmanship adopted for fixed spans will also apply to the structural work of movable bridges under the various conditions of loading.

Wind Pressure.

The minimum wind pressure to be assumed in proportioning the machinery or moving parts of movable bridges, such as trailing wheels on center-bearing swing bridges, operating machinery of swing bridges with unequal arms, and bascule bridges, etc., shall be 20 lb. per sq. ft. on the exposed surfaces of all trusses and the floor system as seen in elevation.

Swing Bridges.

Types of Girders.

The following types of girders and trusses are recommended:

Plate girders, up to 150 ft. span;
Riveted trusses, from 150 to 250 ft. span;
Pin-connected trusses may be used for spans greater than 250 ft.

Conditions of Loading.

Trusses of swing bridges which are continuous over three or four supports shall be calculated for the following conditions:

1.—Bridge open, unloaded;
2.—Bridge closed, no reaction at end from dead load;
3.—Bridge closed, ends lifted to make trusses continuous.

Turn-Tables.

The turn-table may be center-bearing, rim-bearing, or a combination of the two. If a combination table is used, the supporting girders shall be arranged so that some definite portion of the load will be carried to the center. The center-bearing type of turn-table should preferably be used, whenever practicable, and is recommended for single-track bridges up to 500 ft., and for double-track bridges up to 400 ft. span.

Center-Bearing.

Center-bearing turn-tables should be designed so that the entire dead load of the bridge is carried on a center pivot when the bridge is swinging; but, when the bridge is closed, the trusses should rest

at the center on wedges or other substantial supports. These supports must be strong enough to resist the reaction resulting from the live load and impact of the train. Trailing wheels running on a circular track should be provided for the purpose of balancing the bridge and carrying the wind pressure to the track while swinging. The center pivot, as well as the trailing wheels, should be adjustable as to height. The center pivot should be designed so that the disks or rollers can be taken out, examined, or replaced, when the bridge is not in operation, without interfering with the railroad traffic.

Rim-Bearing.

Rim-bearing turn-tables, which carry the bridge on a drum rotating on rollers between two tracks, shall have the center pivot connected to the drum by rigid struts. The object of this pivot is to center the turn-table and hold it in place while the bridge is swinging. The drum shall be designed so that the load is distributed properly over all the rollers. The rollers shall be of such size and number as to carry the entire dead load when the bridge is swinging, and the reaction of the dead and live load and impact when closed. The lower track shall be strong enough to distribute the loads on the rollers over the masonry. The drum shall be designed in accordance with the specifications for plate girders. It shall be provided with effective stiffeners or fillers on both sides of the web at all points of concentrated loading; these stiffeners shall have a close bearing against the upper and lower flanges. The bottom of the lower flange should be planed. The lower track shall be anchored to the masonry with bolts, not less than $1\frac{1}{2}$ in. in diameter and 15 in. long, set in Portland cement grouting.

Rack and Track.

The rack and track segments shall be made in short sections, preferably not more than 5 ft. long. If a cast lower track is used, in case the track is light, as in center-bearing bridges, the rack and track shall preferably be cast in one piece. The maximum pitch of the teeth in the rack shall not exceed 6 in. For small bridges, steel rails may be used for the track.

Pinions.

If the pressure requires a greater pitch than 6 in., two or more pinions shall be used, and they shall be arranged so that the pressure will be distributed equally over all pinions. If two pinions are used, they shall be placed opposite one another.

Brackets.

The brackets to support the pinions gearing into the rack must be made in one piece, so that both bearings can be bored true in line and will not get out of adjustment. They shall be provided with caps so that the pinion shaft can be taken out without removing the bracket.

End-Lifting Apparatus.

All swing bridges must be provided with an effective lifting and locking apparatus at the ends. The lifting apparatus must be strong enough to exert an uplifting force equal to the maximum

negative end reaction of the live load plus 50%, and must have a bearing capacity for the positive maximum end reaction, including impact.

Rail lifts shall be provided, in connection with the end-lifting apparatus, as well as automatic self-acting latches. The latches must be arranged so that they will lock the bridge automatically when in the proper position for closing, but only if the speed is so slow that the shock will do no damage. The end supports should be arranged so that they can easily be adjusted to the proper amount of lift.

Signals.

Bridges carrying railroads shall have at each shore end an automatic signal, and such signals shall be arranged so that the bridge cannot be opened without setting each signal at the danger position, and so that the signals cannot be set to indicate a clear track until the bridge is closed and the rails are in their proper position.

Bascule and Lift Bridges.

The general principles governing the design of swing bridges are also applicable to lift bridges of any kind, as well as to other movable bridges.

Operating Machinery.

Details of Design.

General.

The operating machinery of movable bridges shall be designed and constructed in a substantial manner: all complicated and flimsy contrivances shall be avoided. All parts shall be designed so that they may be easily erected, adjusted and taken apart, and must be accessible for inspection, cleaning and repairs. The fastenings shall be designed so that after all machinery parts are properly set, lined up and adjusted, they will be permanently fixed.

Materials.

Rolled or Forged Steel.—Rolled or forged steel shall be used for bolts, nuts, keys, cotters, pins, axles, shafts, screws, worms and piston rods.

Forged or Cast Steel.—Forged or cast steel may be used for levers, cranks and connecting rods.

Cast Steel.—Cast steel shall be used for pivot stands, couplings, wedge-bearings, rollers, trailing wheels, end shoes, and for racks, tracks and pinions, and toothed wheels of bridges operated by mechanical power.

Cast Iron.—Cast iron may be used for journal boxes, pulleys, drums, eccentrics, and toothed wheels for bridges operated by hand-power only; also for cylinders, pistons, fly-wheels, brake-wheels, and other parts of motors which are usually made of cast iron.

Hardened Steel.—Hardened steel shall be used for pivot disks,

friction-rollers, ball-bearings, and in other similar cases, for the purpose of reducing the bearing surface, abrasion and friction.

Phosphor-Bronze, Brass and Babbitt Metal.—These or other alloys shall be used for the bushing or lining of journal bearings and other rotating or sliding surfaces to prevent seizing, which is likely to occur when steel moves on steel.

Castings. All castings which are to be attached to rough, unfinished surfaces shall be provided with chipping strips. The outer unfinished edges of all ribs, bases, etc., shall be rounded off, and inside corners shall have fillets.

Bolts and Nuts All bolts and nuts, up to 1½ in. in diameter, shall have U. S. Standard V-threads. All nuts and exposed bolt heads shall be of hexagonal shape, and each nut shall be provided with a washer. If the nut bears on an inclined surface, the washer must be beveled. Bolt heads which are countersunk in a casting shall be square.

Lock-Nuts. Nuts which are subject to vibration and frequent changes of load shall have locking arrangements to prevent the gradual unscrewing of the same. If double nuts are used for that purpose, each nut shall be of the standard thickness.

Screws Transmitting Motion. All screws which transmit motion must have square threads.

Tap Bolts. Tap-bolts shall be avoided as much as possible.

Set-Screws. Set-screws shall not be used for fastening wheels, pulleys, pinions, cranks, or any other parts which transmit torsion to shafts or axles. They shall only be used in connection with keys, and for fastening collars to shafts in cases where the collar is not subject to any strain in the direction of the axis of the shaft.

Collars. Collars shall be used wherever necessary to hold the shafting from moving horizontally. Each collar shall have at least two set-screws, set at an angle of 120° to one another.

Keys. All pieces which transmit torsion to shafts or axles shall be fastened with gib-head keys having a taper of ⅛ in. to 1 ft., and shall be seated in grooves, in both hub and shaft. If two keys are used, they shall not be placed opposite, but at an angle of 120° to one another. The minimum width of the key shall be one-fourth of the diameter of the shaft if one key is used, and one-sixth, if two keys are used, and the minimum thickness shall be one-half the width.

Journals. Journals shall be proportioned to resist, not only the various strains to which they are subjected, without exceeding the permissible fiber and bearing strains, but also to prevent a tendency to heat and seize.

Bearings. Steel bearings carrying steel shafts or journals should be babbitted, or have a lining of some other material, preferably bronze. Bearings of steel on steel shall not be used on any rotating or sliding surface, unless provided with metaline plugs, or unless one or preferably each of the surfaces is hardened. The bearings of shafts should be placed as near to the points of loading as possible.

Pivots. Pivots for the centers of turn-tables may revolve on disks, friction-rollers, or balls. Disk-bearings shall preferably consist of three disks, one of phosphor-bronze between two disks of hardened steel, so that the steel will slide on the bronze. The phosphor-bronze shall be of the special kind specified on page 190. Friction rollers or balls shall be made of hardened steel, and they shall run on bearings of the same material. Rollers shall be separated by a spider to prevent them from coming in contact with each other.

Foot-Steps. The foot-steps of vertical shafts may be of axle or tool steel, and shall run on bronze disks.

Axles. When wheels are used in connection with axles, such as trailing wheels for turn-tables, the wheel must be fastened to the axle and allowed to turn in its journal bearings. Wheels shall not be allowed to rotate loose on any axle.

Lubrication. Provision must be made for the proper and effective lubrication of all journals, pivots, or any other moving parts with sliding or rotating surfaces. Closed oil or compression grease cups shall be provided for all journal bearings; where not otherwise accessible, they shall be connected with oil pipes. Oil grooves must be provided wherever necessary for the proper distribution of the lubricant. All oil holes must be easy of access.

Dust Covers. Dust covers shall be provided wherever necessary to protect the sliding and rotating surfaces and prevent dust from mixing with the lubricant.

Shafts. Line shafts, on account of the flexibility of the structure to which they are attached, shall not be continuous, but shall be connected with flexible couplings. Each length of shafting should rest preferably in two regular bearings only, with the couplings on the outside and close to the bearings in opposite directions. In case the bearings or journal boxes are attached to the floor-beams, it may become necessary, in bridges with long panels, to provide intermediate supports in order to reduce the deflection of the shaft. These intermediate supports shall consist of loose-fitting open bearings, the functions of which shall be to prevent the shaft from sagging. The unsupported length of shafting shall not exceed:

$l = 80 \sqrt[3]{d^2}$ for shafts supporting their own weight only;

$l = 50 \sqrt[3]{d^2}$ for shafts carrying pulleys, gearing, etc.;

where l = length of shaft between bearings, in inches; and d = diameter of shaft, in inches.

Line shafts connecting the machinery at the center to that at the ends should run at fairly high speed. The requisite speed reduction should be in the machinery near the end.

Couplings. Couplings to connect shafting shall be claw couplings, and shall be placed as near the bearing as possible. Each half of a coupling shall be fastened rigidly to the end of the shaft, but the

coupling must not be bolted together, in order to allow slight angular motion without twisting and binding the shaft in its bearings. They shall be strong enough to develop the full strength of the shafts to which they are attached.

Toothed Gearing.

Gear wheels should be designed on the assumption that one tooth transmits the whole pressure. In uncut gearing, the pressure should be assumed as coming on a corner of the tooth; but, in machine-cut gearing, it should be assumed as distributed over the whole width of the tooth. All cast pinions shall be shrouded, and no pinion shall have less than twelve teeth. All toothed gearing in operating machinery shall preferably have involute teeth. The minimum width of the teeth should be one and one-half times the pitch; for uncut teeth, generally, the width should be two times the pitch. For cut gearing, the width may be greater, but not more than three times the pitch, excepting for wheels moving at a very high velocity, and those in motors, where the wearing and abrasion have to be considered. In estimating the strength of teeth in bevel wheels, the pitch at the inner circumference shall be taken. Bevel wheels shall preferably be avoided.

Screw Gearing.

Screw gearing should be arranged to have proper lubrication between the sliding surfaces of worms and wheels. To accomplish this, the worm should be placed below the wheel and run in an oil bath. The worm shall preferably be of rolled or forged steel; the wheel may be of bronze or cast iron. Worm-wheels shall have not less than twenty-eight teeth.

Wire-Rope Gearing.

If wire-rope gearing is used to transmit power, the diameter of the drum or pulley should be made as large as possible, and not less than 150 diameters of the rope. The bottom of the groove of the pulley shall be lined with leather or hard wood.

Hydraulic Machinery.

In hydraulic rams, externally-packed plungers shall be used. Pistons packed against the bore of cylinders shall be avoided wherever possible. Packing shall be made in the ordinary stuffing-box, with any approved fibrous packing. The depth of the packing shall be at least six times its thickness. The gland shall always be screwed down tight without compressing the packing, which shall be set out by initial pressure alone. When economy of space requires it, leather rings of rectangular section may be used for packing. These shall be soaked in melted paraffine and bored to fit the plunger, or turned externally to fit the cylinder, but shall be free in all other directions. Pipes for conveying fluid shall be disposed so as to have drainage outlets whereby the whole system can be readily drained.

Workmanship.

General.

All workmanship and finish shall be equal to that of the best practice in modern machine-shops. As the parts of the operating

machinery of movable bridges are generally exposed to the weather, the finish shall be confined to the bearing, rotating, and sliding surfaces, and wherever it is required to produce accurate fits and precise dimensions.

Castings. All castings shall be properly cleaned, and all fins, seams, and other irregularities removed, so that they will have clean, smooth surfaces.

Drainage Holes. Drainage holes, not less than $\frac{3}{4}$ in. in diameter, shall be drilled in all places where water is likely to collect.

Bolts. Unfinished bolts may have a play of $\frac{1}{16}$ to $\frac{1}{8}$ in. in the bolt holes. All turned bolts must have the diameter of the shank at least $\frac{1}{16}$ in. larger than the diameter of the threaded portion, and must have a driving fit in the bolt hole.

Track. All track segments shall be planed on both sides and at the joints. The surfaces on which the rollers bear shall be planed to the true bevel, and have the center line plainly scribed thereon.

Rack. Toothed segments forming the rack shall be accurately fitted; particular care shall be taken to have the pitch of the teeth accurate at the joints. The periphery and the upper face of the teeth shall be planed, and the pitch line scribed thereon. If the rack is separate from the track, the rack segments shall be fitted to those of the track, so as to have the center line of the track exactly concentric with the pitch line of the rack.

Rollers. All rollers shall be turned at the circumference and at the faces of the rim, with the corners chamfered and the center line of the roller scribed on the circumference. The hubs shall be accurately bored and faced at each end.

Centers and Pivot Stands. Pivot stands and center castings of swing bridges shall be properly finished and fitted. Particular care must be taken to have the base faced truly at right angles to the axis, and turned on the circumference concentric with the axis.

Pivots. Steel disks, friction rollers or balls used in pivots, as well as their bearings, must be of tool steel, accurately turned and finished to gauge, and oil-tempered. After hardening, they shall be accurately ground to their final finish. Steel and phosphor-bronze disks shall have their sliding surfaces finished to a high polish.

Journals and Bearings. All journals shall be turned with a fillet at each end, and shall have a good workmanlike fit in their bearings.

Hubs. All hubs of wheels, pulleys, couplings, etc., shall be bored to fit close on the shaft or axle. If the hub performs the function of a collar, the end next to the bearing must be faced. Holes in hubs of toothed gear wheels must be bored concentric with the pitch circle.

Toothed Gear Wheels. The circumference of all gear wheels must be turned. All wheels moving with a velocity of more than 3 ft. per sec. in the

pitch line, as well as all bevel wheels, and those in the gearing of any motor, shall have machine-cut teeth.

Screw Gearing. Threads on worms must be cut, and the teeth of worm wheels must fit the worm accurately.

General. All machinery which is of the regular standard manufactured type, such as steam, gasoline, electric or hydraulic motors, pumps, air compressors, etc., must be guaranteed by the manufacturer as to efficiency, and shall be subject to the approval of the engineer. All motors shall be tested to prove that they fulfill the specified requirements and develop the desired speed and power. The rating of a motor shall be the horse-power determined by the brake test.

Patents. The contractor shall indemnify and save harmless the purchaser against all loss or damage, claims and demands, costs and charges, that may arise or accrue by reason of the adoption or use by the contractor of any patented article, device or improvement furnished by him.

Unit Strains.

Permissible Strains. The unit strains used in designing machinery parts shall not exceed those given in Table 1.

TABLE 1.—Permissible Unit Strains, in Pounds per Square Inch.

Kind of strain. and loading.		Structural steel.	Axle steel.	Steel castings.	Cast iron.	Rolled copper.	Brass.
Tension	(A)	16 000	18 000	12 000	3 000	6 000	3 000
	(B)	10 600	12 000	8 000	2 000	4 000	2 000
	(C)	5 300	6 000	4 000	1 000	2 000	1 000
Compression	(A)	16 000	18 000	16 000	12 000	6 000	3 000
	(B)	10 000	12 000	10 000	8 000	4 000	2 000
Bending	(A)	16 000	18 000	15 000	6 000	.....	.....
	(B)	10 600	12 000	10 000	4 000	.....	.....
	(C)	5 300	6 000	5 000	3 000	.....	.....
Shear	(A)	12 000	14 400	9 000	3 000	3 600	.....
	(B)	8 000	9 600	6 000	2 000	2 400	.....
	(C)	4 000	4 800	3 000	1 000	1 200	.....
Torsion	(A)	10 000	12 000	7 500	3 000	.....	.....
	(B)	6 600	8 000	5 000	2 000	.....	.....
	(C)	3 200	4 000	2 500	1 000	.....	.....

A. For a static load;
B. For a varying load producing strains of tension or compression only;
C. For a varying load producing equal maximum strains in opposite directions, accompanied by shocks and vibrations.

In selecting the working unit strains from Table 1 for designing parts of the operating machinery of a movable bridge, it should be borne in mind that these parts are generally strained in both directions, that the motions are irregular, are frequently accompanied by shocks and vibrations, and that the loads are applied more or less suddenly.

For most machinery parts, such as shafts, axles, gearing, levers, cranks, etc., the figures given for C should be used if the bridge is operated by mechanical power. If hand-power only is used, the values for C, or intermediate ones, may be used, according to the judgment of the designer.

The permissible unit strains for bending (given opposite B)—10 000 for cast steel and 4 000 for cast iron—shall be used for determining the strength of toothed gearing. The teeth in cut gearing shall conform to the following proportions:

$$P = s\ p\ f\ y;$$

where P = Pressure on tooth, in pounds;
s = Permissible unit strain;
p = Pitch, in inches;
f = Face of tooth, in inches;
y = A factor established by experience.

For wheels moving at slow speed (up to about 100 ft. per min.), where strength only is to be considered, $y = 0.05$.

The strength of uncut teeth shall be computed for a face of one and one-half times the pitch, or $P = \frac{3\ s\ p^2\ y}{2}$; which conforms approximately with the assumption that the pressure is carried on one corner of the tooth.

For higher velocities, which tend to increase the shock and wear, this value shall not exceed:

$$y = 0.05\ \frac{10}{\sqrt{v}} = \frac{0.5}{\sqrt{v}};$$

where v = velocity in pitch circle, in feet per minute.

For bronze wheels, the same values shall be used as for cast iron.

Fixed Bearings.

For the permissible unit pressures for fixed bearings of different metals, those in Table 1, for compression, shall be used.

Pressure, in Pounds per Linear Inch, on Rollers at Rest.

Cast iron	$400d$
Rolled and cast steel	$800d$

Where d = diameter of roller, in inches.

Permissible Unit Strains for Bearing on Rotating and Sliding Surfaces.

Maximum Bearing Values for Rotating and Sliding Surfaces, in Pounds per Square Inch.

Bearings on Which the Speed is Slow and Intermittent.

Moving Bearings.

Pivots for swing bridges, hardened tool steel on special phosphor-bronze	3 500
Trunnion bearings for bascule bridges, axle steel on phosphor-bronze	2 000
Wedges, cast iron on bronze	600
Wedges, cast iron on cast iron or structural steel	500
Screws which transmit motion on projected area of thread	200

For Ordinary Cases, Parts Moving at Moderate Speeds.

Hardened steel on hardened steel	2 000
Hardened steel on bronze	1 500
Tool steel (not hardened) on bronze	900
Structural steel on bronze	600
Cast iron on structural steel	400
Cast iron on cast iron	400
On cross-head slides, speed not exceeding 600 ft. per min.	50

In order to prevent heating and seizing at higher speeds, the pressure on pivots or foot-step bearings for vertical shafts and journals shall not exceed:

$$\text{On pivots} \ldots\ldots p = \frac{160\,000}{n\,d}$$

$$\text{On journals} \ldots\ldots p = \frac{300\,000}{n\,d}$$

Where n = number of revolutions per minute;
and d = diameter of journal or pivot, in inches.

For crank pins and similar joints with alternating motion, the limiting bearing values given in the above formula may be doubled.

Roller Bearings.

Permissible Pressure, in Pounds per Linear Inch of Roller in Motion.

For cast iron	$p = 200d$
For steel castings	$p = 400d$
For axle steel	$p = 500d$
For tool steel	$p = 800d$
For hardened tool steel	$p = 1\,000d$

Where p = pressure per linear inch of roller;
and d = diameter of roller, in inches.

The foregoing values are for rollers and bearing surfaces of the same material; if rollers and bearing surfaces are of different materials, the lower value shall be used.

Permissible Pressure on Balls of Hardened Tool Steel Running on Surfaces of the Same Material. Ball Bearings.

For balls running on flat surfaces..... $P = 600d^2$
For balls running in grooves which have a radius of $\frac{3}{4}d$. $P = 1\,200d^2$

Where P = permissible load, in pounds per ball;
and d = diameter of ball, in inches.

Motors.

General. The kind of motor best adapted to any particular case depends upon local conditons, and should be left to the judgment of the engineer.

Hand-Power. If the bridge is operated by hand-power, the number of men and the time required to operate it shall be estimated on the assumption that the force one man can exert on a lever is 40 lb. with a speed of 160 ft. per min., developing about $\frac{1}{3}$ h.p. For calculating the strength of the machinery parts, the power of one man shall be assumed as 125 lb., but 150 lb. shall be the minimum used and applied to the extreme end of the hand-lever on any bridge.

Mechanical Power. If the bridge is operated by mechanical power, the motor shall be of ample capacity to move or turn the bridge at the required speed. All machinery parts shall be designed with sufficient strength to resist the greatest pressure which can be exerted by the motor, using the specified permissible strains. No matter what mechanical power is used, all bridges shall also be provided with hand-power operating machinery.

Hand-Brakes. Friction brakes, to be operated by hand or foot, shall be provided for all bascule and lift bridges, and for all swing bridges where the motor is located in the operator's house. They shall be attached to the secondary shaft of the motors which connect to the moving gear, and shall have sufficient capacity to stop or hold the moving span in any position under all conditions.

Safety Gates. In cities, all movable bridges, carrying highway traffic, which leave an opening in the floor when the bridge is open for navigation (as in swing bridges), shall be provided with safety gates. These gates shall be arranged so that the bridge cannot be opened before the gates are closed, and so that the gates cannot be opened before the bridge is closed and locked.

Operator's House.

Wherever mechanical power of any kind is to be used for operating a movable bridge, a suitable house shall be provided for the operator. The house shall be of such dimensions as required for the purpose for which it is to be used. It shall be placed in a position where the operator can observe the signals and see the approaching vessels and trains, and with enough windows of sufficient size so that his view will not be obstructed. If the operator's house is above or below the floor of the bridge, suitable steel or iron stairs with railings shall be provided to lead from the floor of the bridge to the floor of the operating house. The house shall be of fire-proof construction, consisting of a steel frame, steel floor-joists and a fire-proof floor. If the house contains motors and machinery, the floor shall preferably consist of steel plates, but, if the motors are located elsewhere, the floor between the joists may be of concrete construction. The sides and roof shall be of metal, concrete, or any other non-combustible material.

Heating.

Whenever the climatic conditions require it, provision shall be made for heating the operator's house. If steam power is used, the house shall be heated by a steam coil or radiator fed from the boiler. If electric power is used, the heat may be supplied by electricity. If gasoline is used, or any other power which cannot be utilized for heating, a coal, wood, petroleum, or gas stove, as directed by the engineer, shall be provided.

Steam Motor.

If a steam engine is used, it shall consist of a double-cylinder, reversing engine, the piston speed of which shall not exceed 200 ft. per min.; it shall develop the desired power and speed with a steam pressure of 50 lb. per sq. in. The engine shall be connected to the operating machinery by an approved friction clutch, arranged so that the moving and locking machinery can be operated alternately or stopped without stopping the engine.

Boiler.

The steam shall be generated by one or two upright, tubular boilers, each of which shall have twice the capacity of the engine. The boilers shall be designed for a steam pressure of 150 lb. per sq. in., and adapted to the kind of fuel specified by the engineer; they shall be of open-hearth steel in accordance with the specifications for boiler plates appended hereto. They shall be cased in asbestos, covered with Russian iron.

Engine-Room.

The engine-room shall be provided with a steel water tank of sufficient capacity, a duplex, steam feed-pump, and an injector for each boiler, with necessary pipes and connections for feeding boilers separately or together, steam water-lifters with necessary strainers, flexible hose, and piping to lift the water from the river into the tank, a coal hoist and a steel coal-bin of sufficient capacity. The engine-room shall be provided with a suitable indicator for recording the positions of the moving span in turning and lock-

ing. A work bench with a full set of machinist's tools shall be provided, such as a vise, wrenches, chisels, hammers, files, oilers, oil-cans, and oil-tank. A whistle of suitable size shall be provided. All piping, where necessary, shall be covered with the best sectional covering.

Gasoline Motors.

If a gasoline motor or other internal-combustion motor is used, a low-speed engine of the most substantial kind shall be selected, the maximum piston speed of which shall not exceed 400 ft. per min. The engine shall have a reversing gear provided with approved friction clutches, to be operated by a hand-wheel. The countershaft connecting the engine with the operating machinery shall be provided with disengaging couplings, arranged so that the moving and locking machinery can be operated alternately and in either direction without stopping the engine. Motors of 10 h.p. and more shall be started by compressed air. The engine-room shall be provided with a water tank of sufficient capacity. The gasoline tank shall be located outside of the engine-house. The engine-room shall be provided with indicators for recording the positions of the moving span, and lifting, and locking apparatus. A work bench with a full set of machinist's tools, etc., shall be provided, the same as specified for steam motors.

Electric Motors.

If electricity is used as the motive power, the motors shall be of the railway type, series wound, single reduction, multipolar, water-proof, with steel frame and iron-clad armature of the required capacity. The capacity of each motor shall be estimated at normal speed and whatever voltage available according to the rating of the American Institute of Electrical Engineers, and be capable of carrying an overload of 33⅓% for 30 min. or 50% for 5 min. without injurious heating. The armature speed shall not be more than 600 rev. per min. With each motor shall be furnished a cut pinion and gear with a reduction such that the countershaft will make aproximately the required number of revolutions per minute (generally 100 to 125) under full-load rating. These pinions and gears shall be protected by a removable gear case. Motors connecting to vertical shafts should preferably have a vertical axis in order to avoid gearing.

All motors shall be of standard types in common use in order that extra parts may be readily procured, and shall be subject to the approval of the engineer.

Extra Parts.

The contractor shall furnish for each operating motor one extra armature, one extra field coil, one extra pinion, and one extra split gear. All such extra parts shall be fitted ready to place on the motors.

Controllers.

Controllers shall be placed in the operating house. Each motor or set of motors shall have one controller, that is, if two motors work

together, they shall be connected to one controller. They shall be of the reversible, series parallel type, fitted with interlocking, reversing cylinders, magnetic blow-out, etc., and shall be capable of varying and maintaining the speed of the motors from slow speed at the starting point to a maximum speed when full on, without sparking and without shock or jar. They shall be of ample carrying capacity to transmit for 30 min. 33⅓% more than the normal power required by the motors at full load, or transmit for 5 min. 50% more than the normal amount required by the motors, without injurious heating.

Resistance. Suitable resistances shall be furnished, so that the motors will start from a stand-still and attain full speed without causing sparking at the commutators of the motors, or without shock or jar to the bridge.

Cables. Unless the current supply is taken from more than one source, it shall be conducted to the switch-board in two independent conductors: one for the supply and one for the return current. These conductors, if the power has to cross a channel, shall consist of steel-armored submarine cables. Each cable shall be of sufficient capacity to carry safely the necessary current to operate the bridge with full overload on the motors as herein specified. Each cable shall be composed of nineteen strands of tinned copper wire of not less than 98% conductivity, insulating walls of rubber not less than $\frac{5}{32}$ in. thick containing not less than 30% of pure Para rubber, one winding of tape, a lead sheath $\frac{3}{32}$ in. thick containing 3% of tin alloy, a substantial jute and asphalt serving, and an armor of galvanized-steel wire of suitable size for the diameter of the cable. The cables shall show, at 60° fahr., an insulating resistance of 500 megohms per mile after 5 min. electrification.

In the case of swing bridges, the cables shall be brought up, on or through the center pivot, with collector rings for the purpose of conducting the current to the controlling apparatus while the bridge is swinging. The collector rings shall be protected by a removable metallic casing.

Wiring. All wiring between the switch-boards, motors, and lights shall be of the best grade of rubber-covered, double-braided copper wire, and put up securely on porcelain insulators. No wires smaller than No. 14, B. & S. gauge, shall be used. All wires shall be drawn into place free from mechanical injuries, in loricated iron conduits located and arranged so as to be easily accessible for examination and repairs. All wiring shall be of sufficient capacity to carry safely the current required, with the over-load specified, without injurious heating.

Grounds. All ground connections to the structure shall be made with proper soldered terminals secured to copper plates of ample area

fastened in contact with the structural work, or in other manner satisfactory to the engineer. Care must be taken to locate the connections so that there will be ample metal and proper circuits to return the currents without damage to the structure.

Cut-Outs. An automatic circuit breaker, equal to the I. T. E. standard switch-board type, shall be placed on the motor circuit on each switch-board. Each cable, each line of motors, and each line of lighting, signal, indicator or other circuit shall be protected by suitable fuses of a pattern approved by the engineer.

Meters. One 600-volt meter with 5-volt graduation, and one 300-ampere shunt ammeter with 2-ampere graduation, both equal in quality to the Western type "F," shall be placed on each switch-board.

Switches. A suitable switch, of quick-break, railway type, shall be provided for each motor circuit and for each supply wire. All switches shall have ample carrying capacity for their respective loads with the specified over-load, but no switch shall have a capacity of less than 50 amperes.

Switch-Boards. There shall be placed in each operator's house a marble switch-board large enough to allow all necessary meters, switches, circuit breakers, fuses, etc., to be located thereon without crowding, so that each device can be reached and operated quickly and safely by the bridge tender. All switches, fuses, signal circuit, and submarine cable terminals shall be suitably named and labeled with neat metal plates, in accordance with their purpose and use. Switch-boards shall be located behind the controllers and convenient thereto, and placed at an angle of 45° with the side of the house. They shall be mounted on substantial iron supports and be thoroughly braced to the wall.

Electrical Indicators. An electrical indicator of approved design shall be placed in front of the controller, recording the movements of the bridge and the lifting and locking apparatus.

Contacts. The contacts or electrical devices for making or breaking the electric circuits to operate the electric indicators, or similar connections, shall be substantial in construction, reliable in action, completely protected from the weather, and shall be submitted to the engineer for approval.

Lights. In each operator's house shall be placed ten 16-c.p. lights, and additional lights about the machinery and such other points as the engineer may direct. Lights placed outside shall have water-proof sockets. Each set of lights shall be controlled by a switch on the switch-board in the operator's house.

Telephone. In each operator's house shall be placed a telephone, complete, with receiver, transmitter, battery, and magneto bell, and also a push-button and signal bell connected by the cable.

Signals. Suitable semaphores and signal lights shall be provided, as directed by the engineer.

All the electrical equipment, apparatus, etc., shall be of the most substantial character and of good finish, and all material and workmanship shall be subject to the approval of the engineer. The contractor, before beginning work, shall submit for approval complete plans with details and specifications showing the wiring and the parts he proposes to install. The working of the machinery and its efficiency to operate the bridge shall be tested to prove that it fulfills the specified requirements.

Specifications for Special Metals Used for Machinery Parts.

Steel Castings.

Process of Manufacture.

1.—Steel for castings may be made by the open-hearth or crucible process. All castings shall be annealed unless otherwise specified.

Chemical Properties.

2.—Phosphorus ..... 0.05% maximum.
Sulphur ..... 0.05% maximum.

Tensile Tests.

3.—Minimum physical qualities as determined on a standard test specimen of ½ in. diameter and 2 in. gauged length:

Tensile strength, in pounds per square inch....	70 000
Elongation: percentage in 2 in.....	18
Contraction of area: percentage.....	25

Drop Test.

4.—A test to destruction may be substituted for the tensile test, in the case of small or unimportant castings, by selecting three castings from a lot. This test shall show the material to be ductile, free from injurious defects, and suitable for the purpose intended. A lot shall consist of all castings from the same melt or blow, annealed in the same furnace charge.

Percussive Test.

5.—Large castings shall be suspended and hammered all over. No cracks, flaws, defects, or weakness shall appear after such treatment.

Bending Test.

6.—A specimen (1 in. by ½ in.) shall bend, cold, around a diameter of 1 in., through an angle of 90°, without fracture on the outside of the bent portion.

Number and Location of Specimens.

7.—The number of standard test specimens shall depend upon the character and importance of the castings. A test piece shall be cut, cold, from a coupon to be moulded and cast on some portion of one or more castings from each melt or blow, or from the sink-heads (in case heads of sufficient size are used). The coupon or sink-head must receive the same treatment as the casting or castings, before the specimen is cut out, and before the coupon or sink-head is removed from the casting.

Sample for Chemical Analysis.

8.—Turnings from the tensile specimen, or drillings from the bending specimen, or drillings from the small test ingot, if pre-

ferred by the inspector, shall be used to determine whether or not the steel is within the limits in phosphorus and sulphur specified in Paragraph 2.

Finish. 9.—Castings shall be true to pattern, free from blemishes, flaws or shrinkage cracks. Bearing surfaces shall be solid, and no porosity shall be allowed in positions where the resistance and value of the casting for the purpose intended will be seriously affected thereby.

Steel Forgings.

Manufacture. 1.—Steel forgings may be made by the open-hearth or crucible process.

Chemical Properties. 2.—Phosphorus ..... 0.04% maximum.
Sulphur ..... 0.05% maximum.

Physical Properties. 3.—Minimum physical properties as determined on a standard turned test specimen of ½ in. diameter and 2 in. gauged length:

Tensile strength, in pounds per square inch... 55 000 to 65 000
Elongation: percentage in 2 in..... 28

Bending Test. 4.—A specimen (1 in. by ½ in.) shall bend, cold, 180°, around a diameter of ½ in., without fracture on the outside of the bent portion. The bending may be effected by pressure or by blows.

Number and Location of Tensile Specimens. 5.—The number and location of the test specimens to be taken from a melt, blow, or forging shall depend upon their character and importance, and, therefore, must be regulated by individual cases. The test specimen shall be cut, cold, from the forging, or full-sized prolongation of the same, parallel to the axis of the forging and half way between the center and the outside; the specimens shall be longitudinal, *i. e.,* the length of the specimen shall correspond with the direction in which the metal is most drawn out or worked. When forgings have large ends or collars, the test specimens shall be taken from a prolongation of the same diameter or section as that of the forging back of the large end or collar. In the case of hollow shafting, either forged or bored, the specimen shall be taken within the finished section prolonged, halfway between the inner and outer surfaces of the wall of the forging.

Sample for Chemical Analysis. 6.—Turnings from the tensile specimen, or drillings from the bending specimen, or drillings from the small test ingot, if preferred by the inspector, shall be used to determine whether or not the steel is within the limits in chemical composition specified in Paragraph 2.

Finish. 7.—Forgings shall be free from cracks, flaws, seams, or other injurious imperfections, and shall conform to the dimensions shown on the drawings furnished by the purchaser, and shall be made and finished in a workmanlike manner.

Annealing. 8.—All forgings shall be annealed.

Axle Steel.

Manufacture. 1.—Axle steel may be made by the open-hearth or crucible process.

Chemical Properties. 2.—Phosphorus ..... 0.05% maximum.
Sulphur ..... 0.05% maximum.

Physical Properties. 3.—Minimum physical properties, as determined on a standard turned test specimen of ½ in. diameter and 2 in. gauged length:

Tensile strength, in pounds per square inch... 80 000
Elongation; percentage in 2 in..... 20

Bending Test. 4.—A specimen (1 in. by ½ in.) shall bend, cold, 180°, around a diameter of 1½ in., without fracture on the outside of the bent portion. The bending test may be made by pressure or by blows.

Sample for Chemical Analysis. 5.—Turnings from the tensile test specimen, or drillings from the small test ingot, if preferred by the inspector, shall be used to determine whether the melt is within the limits in chemical composition specified in Paragraph 2.

Boiler Plate.

Manufacture. 1.—The steel used for boilers and fire-boxes shall be made by the open-hearth process.

Chemical Properties. 2.—Phosphorus .....0.04% maximum.
Sulphur .....0.04% maximum.

Physical Properties. 3.—The physical properties required shall be as follows:

Tensile strength, desired, in pounds per square inch 60 000
Elongation; minimum percentage in 8 in. $\frac{1\,500\,000}{\text{Ultimate strength.}}$
Character of fracture.....Silky.
Cold bends, without fracture.....180°, flat.

Allowable Variations. 4.—The ultimate strength shall come within 4 000 lb. of that desired.

Chemical Analysis. 5.—Chemical determinations of the percentage of carbon, phosphorus, sulphur and manganese shall be made by the manufacturer from a test ingot taken at the time of the pouring of each melt of steel, and a correct copy of such analysis shall be furnished to the engineer or his inspector. A check analysis shall be made from the finished material, if called for by the purchaser, in which case an excess of 25% above the required limits will be allowed.

Form of Specimens. 6.—Specimens for tensile and bending tests for plates shall be made by cutting coupons from the finished product, which shall

have both faces rolled, and both edges milled to the usual form of the standard test specimen, 1½ in. wide on a gauged length of at least 9 in.; or with both edges parallel.

Nickel-Steel.

Manufacture.

1.—Nickel-steel shall be made by the open-hearth process.

Chemical Properties.

2.—

	Plates, shapes and bars.	Rivets.
Phosphorus shall not exceed	0.04%	0.04%
Sulphur " " "	0.05%	0.04%
Nickel, not less than	3.00%	3.25%

Physical Properties.

3.—The physical properties required shall be as follows:

	Plates, shapes, bars and forgings. Pounds per square inch. Minimum.	Rivets.
Tensile strength	80 000	60 000 to 70 000
Elastic limit	50 000	40 000 min.

Elongation, percentage in 8 in., for plates, shapes, bars and forgings;

$$\text{and also for rivets} = \frac{1\,600\,000}{\text{ult. strength}} = \text{min.}$$

Elongation, percentage in 2 in., for forgings = 25 per cent.

Bending Tests.

4.—Specimens cut from plates, shapes and bars shall bend, cold, 180°, around a diameter of three times their thickness, without fracture on the outside of the bent portion.

5.—Specimens cut from forgings (1 in. by ½ in.) shall bend, cold, 180°, around a diameter of 1 in., without fracture on the outside of the bent portion.

6.—Each rivet rod shall bend 180°, flat, on itself, without fracture on the outside of the bent portion.

7.—Rivet rods shall be tested as rolled.

Character of Fracture.

8.—The fracture of all tension tests shall show a fine silky texture, of a uniform bluish gray or dove color, free from black or brilliant specks, and shall show no sign of crystallization.

Annealing.

9.—All nickel-steel forgings shall be properly annealed.

Full-Sized Tests.

10.—Annealed eye-bars and similar members, when full-sized pieces are tested, shall comply with the following requirements:

Minimum ultimate tensile strength, in pounds per square inch..... 75 000.
Minimum elastic limit, in pounds per square inch, 45 000.
Minimum elongation in 10 ft., including fracture, 12%.
The fracture shall be mostly silky, and free from coarse crystals.
Full-sized pieces shall bend, cold, 180°, around a diameter of twice their thickness, without fracture.

Tool Steel.

1.—This steel is generally used for parts which require hardening or oil-tempering, such as pivots, friction rollers, ball-bearings and springs.

Manufacture. 2.—Tool steel shall be made by the open-hearth or crucible process.

Chemical Properties. 3.—

Carbon	1.00%	minimum.
Phosphorus	0.04%	maximum.
Sulphur	0.04%	"
Manganese	0.50%	"

Phosphor-Bronze.

Special phosphor-bronze shall be used for high pressures and slow speed.

Tests. 1.—The metal shall have a minimum elastic limit in compression of 24 000 lb. per sq. in.

Test Pieces. 2.—A test piece shall be cut from a coupon to be moulded and cast on some portion of each casting. Test pieces shall be one-inch cubes, finished.

Composition. 3.—Phosphor-bronze composed of the following ingredients and of the following proportions has given satisfactory results:

Copper	80%
Tin	15%
Phosphor-Tin	5%
Phosphorus	0.2%

Babbitt Metal.

Composition. 1.—Babbitt metal composed of the following ingredients and of the following proportions has given satisfactory results and a low coefficient of friction (0.03 to 0.04):

Tin .....2 parts.
Zinc .....1 part.
Antimony, 5% of the weight of the tin and zinc.

Method of Mixing. 2.—Melt the zinc and antimony separately. When both metals are melted, add the antimony to the zinc, and stir the mixture with an iron ladle. The tin is then added cold, and, when melted, the mixture is stirred thoroughly. Before pouring, a little sal-ammoniac is thrown on the surface to collect impurities.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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TYPHOID MORTALITY IN SOUTH BETHLEHEM, PA.*

BY MANSFIELD MERRIMAN AND WINTER L. WILSON, MEMBERS, AM. SOC. C. E.

Messrs. Merriman and Wilson.

Referring to the discussion by J. P. A. Maignen, Assoc. Am. Soc. C. E., on the paper by Messrs. Hazen and Hardy, printed in *Transactions*, Vol. LVII, p. 383, the writers desire to present a full record of the typhoid mortality in South Bethlehem, Pa.

Mr. Maignen says "it may be of interest to know the influence which filtration has had on this disease in South Bethlehem," and then he gives figures which show 54 deaths from typhoid and enteric fever in 1903 and 1904, before the installation of the filter plant in November, 1904, and no deaths in 1905 and 1906. Two inferences are evidently intended to be drawn from these statements: First, that the normal mortality from typhoid before 1905 was about 27 deaths per year, or at the rate of about 180 per 100 000 of the present population; and second, that the influence of the filtration of the water supply has been to cause this disease practically to disappear. The first of these inferences is entirely unjustified, as the following statistics will prove; and the second will also be shown to have little or no validity.

The statistics given by Mr. Maignen are incomplete, as they cover only a short period, while also the cases and deaths given by

* This discussion, called forth by the discussion by J. P. A. Maignen, Assoc. Am. Soc. C. E., on the paper by Messrs. Hazen and Hardy, "Works for the Purification of the Water Supply of Washington, D. C." (*Transactions*, Vol. LVII, p. 307), was received too late to be printed with that paper in *Transactions*. It is printed here for the information of those interested in the subject.

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him for 1903 and 1904 are much greater in number than those recorded in the files of the Board of Health of the Borough of South Bethlehem. The writers are unable to explain this discrepancy, except by the assumption that the figures include localities outside of the limits of the borough where the same water supply is used. This explanation, however, does not account for his statement that only 8 cases and no deaths occurred in 1905 and 1906, for the official records of the Borough of South Bethlehem show 22 cases and 5 deaths between January 1st, 1905, and November 1st, 1906.

In order that the facts, and all the facts, regarding the mortality from typhoid fever in the Borough of South Bethlehem may be known, Table 1 is presented. This table has been compiled by the writers from the records of the Board of Health.

TABLE 1.—DEATHS FROM TYPHOID FEVER IN SOUTH BETHLEHEM, PA.

	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906
Jan.	.....	.....	.....	.....	.....	.....	.....	1	5	1	.....	2
Feb.	.....	.....	1	.....	.....	.....	.....	1	4	.....	.....	.....
Mar.	1	.....	1	.....	.....	.....	1	2	11	1	.....	.....
Apr.	.....	.....	.....	.....	.....	.....	2	1	1	2	1	.....
May	.....	.....	.....	.....	.....	1	1	.....	1	1	.....	.....
June	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	.....
July	.....	.....	.....	.....	.....	.....	.....	.....	1	1	1	.....
Aug.	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	1	.....
Sept.	1	.....	2	.....	.....	.....	.....	2	.....	2	.....	.....
Oct.	1	.....	1	.....	2	1	.....	.....	1	.....	.....	.....
Nov.	.....	.....	1	.....	.....	.....	1	3	.....	.....	.....	.....
Dec.	.....	2	1	.....	.....	1	.....	1	1	.....	.....	.....
Totals....	3	2	7	0	2	3	5	10	26	7	3	2

An examination of these figures shows that there were no deaths from typhoid fever in 1898, that the number of deaths increased each year until it reached a maximum in 1903, and has since decreased. There was, in fact, an epidemic of typhoid fever in 1903, in which year 147 cases were reported to the Board of Health and 26 deaths occurred. The cause of this epidemic was attributed by some to the water supply and by others to the milk supply, the weight of evidence being that it was due to the water. Whatever may have been the cause, the epidemic was over in the fall of 1903, and the typhoid mortality for 1905-1906 has been at practically the same rate as in the years 1899-1900. The total number of deaths from typhoid during the years 1895-1902 was 32, or an average of 4 deaths per year, and this may be regarded as the normal typhoid mortality in South Bethlehem, uninfluenced either

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by epidemics or by filtration. The epidemic of 1903, due probably to pollution of the water supply, caused this normal rate of 4 to be raised to 26. The average mortality in the two years, 1905-1906, is 2.5, but it is questionable whether the decrease from 4 to 2.5 can properly be ascribed to filtration when it is seen that the same average of 2.5 is found for the two years, 1899-1900, and a still lower one for the two years, 1898-1899.

South Bethlehem derives its water supply from the Lehigh River. Allentown, five miles up stream, derives its water supply from springs, and discharges a considerable quantity of sewage into the same river. Table 2 gives the facts regarding the mortality from typhoid fever in Allentown, as compiled by the writers from the records of the Board of Health of that city:

TABLE 2.—DEATHS FROM TYPHOID FEVER IN ALLENTOWN, PA.

	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906
Jan.	.....	2	2	2	1	2	.....	1	1	1	1	.....
Feb.	3	1	3	.....	2	1	.....	3	3	2	2	1
Mar.	2	4	1	2	.....	4	.....	8	2	.....	1	3
Apr.	7	.....	1	.....	1	.....	4	2	.....	3	1	2
May	3	.....	.....	.....	.....	.....	2	1	2	1	.....	2
June	1	1	.....	2	2	.....	2	2	2	2	1	2
July	4	.....	.....	3	8	.....	1	.....	2	.....	1	1
Aug.	10	2	2	4	3	.....	1	3	.....	1	3	3
Sept.	8	1	.....	3	3	1	4	2	1	.....	1	1
Oct.	7	4	1	3	2	1	1	27	2	4	1	1
Nov.	1	.....	2	1	2	2	.....	11	1	1	3	2
Dec.	2	5	1	2	.....	.....	2	5	1	2	3	.....
Totals...	48	20	13	22	24	11	17	65	17	17	18	18

Table 2 shows fluctuations similar to those in the table for South Bethlehem, the number of deaths being greater because of the larger population of Allentown. The typhoid epidemic of 1903 in South Bethlehem was preceded by one in Allentown in 1902; the rise of the number of deaths in years prior to 1902, and the subsequent decrease, show a similarity to the fluctuations in the figures for South Bethlehem. The average mortality for the seven years preceding 1902 is 22 per year, and this may be regarded as the normal rate for Allentown independent of epidemics or filtration. The epidemic of 1902 caused the normal yearly mortality rate of 22 to rise to 65, and then, for the four years following, the average rate dropped to about 18. This drop in typhoid mortality after 1902 cannot be attributed to filtration, since Allentown has no plant for this purpose.

In order to compare properly the foregoing statistics of typhoid mortality for South Bethlehem and Allentown, it is necessary to

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reduce them to a common basis, and the number of deaths per 100 000 of population has been computed. In doing this, the population of the two towns for each year was first determined by interpolation from the census records, as follows:

	1895	1896	1897	1898	1899	1900
South Bethlehem ..	11 770	12 060	12 360	12 650	12 950	13 241
Allentown	30 320	31 340	32 360	33 380	34 400	35 416
	1901	1902	1903	1904	1905	1906
South Bethlehem ..	13 530	13 830	14 120	14 420	14 700	15 000
Allentown	36 430	37 460	38 480	39 550	40 620	41 690

The deaths from typhoid fever per 100 000 of population are then as follow for each of the years, 1895-1906:

	1895	1896	1897	1898	1899	1900
South Bethlehem...	25.5	16.6	56.6	0.0	15.4	22.7
Allentown	158.3	63.8	40.2	65.9	69.8	31.1
	1901	1902	1903	1904	1905	1906
South Bethlehem...	37.0	72.3	184.8	48.5	20.4	(13.3)
Allentown	46.7	173.6	44.2	43.0	44.3	(43.2)

These figures show the average yearly typhoid death rate per 100 000 of population for the eleven years, 1895-1906, to be 45.4 for South Bethlehem and 71.0 for Allentown. Omitting the epidemic years of 1903 at South Bethlehem and those of 1895 and 1902 at Allentown, the average annual death rate per 100 000 of population has been 31.5 for South Bethlehem and 49.9 for Allentown. The epidemic of 1903 in South Bethlehem caused the typhoid mortality for that year to be nearly six times the average rate, while that at Allentown in 1902 caused the rate for that year to be about three and one-half times the average rate. In the second year following these epidemics, the typhoid death rate in both towns dropped below the average. The remarkable similarity of the curves for the two towns leads to the probable conclusion that the typhoid epidemic of 1903 in South Bethlehem might have been due to that which prevailed in Allentown in 1902. This conclusion is strengthened by the facts that the water supply of the Lehigh River is always more or less polluted by the drainage of Allentown, and that the two epidemics were separated only by an interval of about four months. The drop of both curves in the two years following the epidemics, together with the known fact that the Allentown supply has never been filtered, furnishes evidence that the decrease of typhoid fever in South Bethlehem in 1905 and 1906 cannot fairly be attributed to the filtration plant which was put into operation in November, 1904.

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LIGHTHOUSE CONSTRUCTION IN THE PHILIPPINES.

Discussion.*

By Charles E. L. B. Davis, M. Am. Soc. C. E.

Mr. Davis.

Charles E. L. B. Davis, M. Am. Soc. C. E.† (by letter).—The writer has read this paper with much interest, and wishes to offer some criticism on the asserted indestructibility of the native hard woods by the teredo and the white ant.

In the harbor works of the Port of Manila there were two dredges of the endless-chain bucket type, built by the Spaniards and used by the Philippine Government in dredging the mouth of the Pasig River. These dredges dug up at various times pieces of native wood, and several pieces of molave were in the office of the works of the port on the Malecon Drive in Manila when the writer left the islands. These pieces had probably dropped from the decks of passing boats, and, like most of the native woods, being heavier than water, had sunk to the bottom. These pieces of molave were honeycombed by the teredo. The appearance of the wood indicated that it had not been long in the water. In addition to the boring of the teredo, there were several perfectly round, smooth holes, about $\frac{5}{8}$ in. in diameter, at right angles to the direction of the fiber of the wood and passing entirely through the specimens. Apparently, these were made by the same animal that bores similar holes in the soft adobe stone used by the Spaniards in the con-

*This discussion (of the paper by Spencer Cosby, M. Am. Soc. C. E., printed in *Proceedings* for November, 1906), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

†Colonel, Corps of Engineers, U. S. Army.

Mr. Davis.

struction of the sea-walls at the mouth of the Pasig River, several specimens of which the writer obtained alive from the cavities of this stone. It is one of the family of Pholadidæ, a bivalve mollusk that bores into wood and stone.

It was for this reason that the wharves or slips which are to be built for the accommodation of vessels in the harbor inside of the breakwater at Manila are to have concrete piers on pile foundations, with steel superstructures.

With reference to the statement that by allowing no wood to come in contact with the ground, and sinking the lower parts of the posts in concrete piers, as a precaution against the attack of the white ant, the writer will relate his experience. During a portion of his stay in Manila he lived on Nozaleda Street, in one of the buildings erected by the Spaniards for occupancy by the engineer officers of their army. The United States Quartermaster's Department had built, over the doors and windows, rain sheds of corrugated galvanized iron; those over the windows were supported by brackets and those over the doors by posts on concrete blocks, as shown by the photograph, Plate XI. These posts were of native hard wood, but, as they were painted, the writer does not know whether or not they were of molave.

On the further post, as can be plainly seen in the photograph, was a crack, either a wind-shake or a sun-check. Sitting on the porch one day, the writer observed a winged ant flying around this crack, evidently examining it very carefully, alighting frequently and going into it as far as possible. A few mornings later, it was seen that a white ant gallery or tunnel had been built from the ground up over the cement base and about a foot or more up the post in a direct line toward the crack. The writer scraped the tunnel off and killed the ants by stamping on them; but, a few mornings afterward, he observed that the same thing had taken place, a tunnel had been built during the night a little higher up the post than before. This time the writer scraped off the gallery, poured kerosene over the ants, which killed them instantly, and saturated the ground with the oil, which seemed to discourage the ants, for he saw no further attempts to enter the post during his stay in the house.

Evidently, any opening, however small, will afford an entrance to this pest, which will go to great trouble to reach the opening, and great precautions will have to be taken to ensure freedom from the attacks of this insect.

Johnson's Cyclopedia, in the article on Termites, says there are several kinds of individuals in each nest: (1) sexual individuals, kings and queens; (2) neuters, abortive males and females, workers and soldiers; (3) larvæ of males and females, workers and soldiers;

PORCH OF RESIDENCE IN MANILA, SHOWING CRACK IN POST ATTACKED BY WHITE ANTS.



PORCH OF RESIDENCE IN MANILA, SHOWING CRACK IN POST ATTACKED BY WHITE ANTS.

and (4) nymphs of the same. The males and females when they come to maturity have wings. The workers measure from $\frac{1}{8}$ to $\frac{4}{8}$ in. in length, have soft, white bodies, and no eyes. They habitually avoid air and light. When they desire to reach a certain point, a covered gallery is immediately built to that point, that they may reach it unseen. Mr. Davis.

The above description from the Cyclopedia corresponds to the writer's observations as far as they extended. The ants he saw, that is, the workers, looked like white, blind grubs, about $\frac{1}{4}$ in. long, and were very active when disturbed. The gallery was made of earth moistened with some secretion of the ant, and was about the color of potter's clay when fresh; it becomes very hard in time. It is about the size of a lead pencil in exterior diameter, and adheres very firmly to wood and stone. They only work on the gallery at night or in the dark.

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PAPERS AND DISCUSSIONS.

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RAINFALL, AND RUN-OFF IN STORM-WATER SEWERS.

Discussion.*

By William C. Hoad, Assoc. M. Am. Soc. C. E.

Mr. Hoad.

William C. Hoad, Assoc. M. Am. Soc. C. E. (by letter.)—The fact that the run-off per unit of area from small areas is greater than that from large areas is clearly recognized, and is conceded to be due to the higher maximum rates of rainfall obtaining for the short period of time necessary for the concentration of the flood waters from all parts of the small area than for the longer period required for concentration in the case of the larger area. This is taken account of, in many of the formulas, by introducing some power of the area, A, or of both the area and the general slope, S, into the expression for the run-off, thus assuming that the time of concentration is a function of the area. Even when the rational formula, $Q = ACI$, is used, the time of concentration, for which the intensity, I, is taken, is oftentimes determined by a subordinate formula involving the area and the slope. The writer has in the past spent considerable time in attempting to obtain a satisfactory expression for the time, T, in terms of some function of the area, A, and its general slope, S, with the idea in view of incorporating such an expression with a rainfall formula and a variable run-off factor, but has finally given it up. He had come to believe, moreover, that this cannot

* This discussion (of the paper by Charles Emerson Gregory, Assoc. M. Am. Soc. C. E., printed in *Proceedings* for November, 1906) is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

be done with as close an approach to accuracy as is demanded by the importance of the results involved. Mr. Hoad.

The time of concentration of any given area is a function of the distance through which the water falling upon the extreme limits must pass through in order to reach the point in question, and of its velocity of flow in passing through this distance. This distance is not a function of the area, for areas of the same size but of different shapes give different distances, as may be seen by Fig. 12 and Table 12. Here, with the assumed directions of flow,

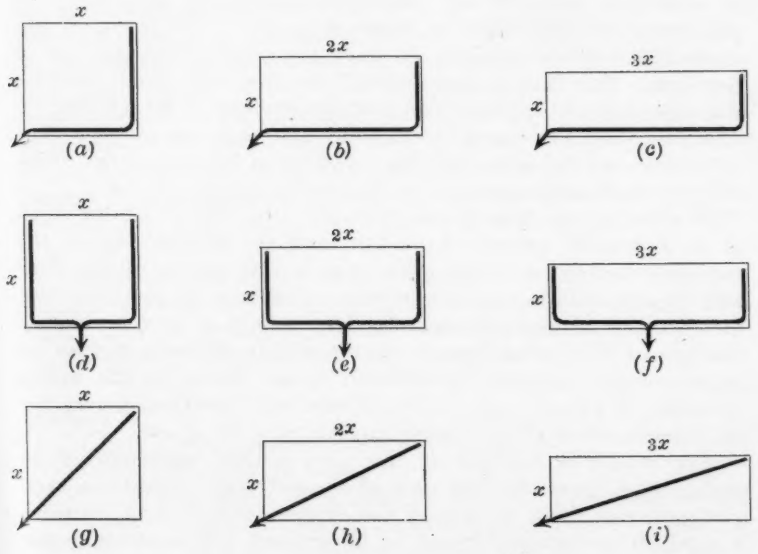


FIG. 12.

TABLE 12.—RELATION BETWEEN AREA AND DISTANCE, FOR DRAINAGE AREAS OF DIFFERENT SHAPES, AND FOR DIFFERENT GENERAL ROUTES FOR SEWERS, AS INDICATED IN FIG. 12.

(*a*) $D = 417\sqrt{A}$	(*b*) $D = 443\sqrt{A}$	(*c*) $D = 482\sqrt{A}$
(*d*) $D = 313\sqrt{A}$	(*e*) $D = 296\sqrt{A}$	(*f*) $D = 302\sqrt{A}$
(*g*) $D = 296\sqrt{A}$	(*h*) $D = 330\sqrt{A}$	(*i*) $D = 381\sqrt{A}$

indicated by the arrows, the ratios between the distances and the square root of the area are seen to vary from 295 to 483. Moreover, it is a matter of common observation that, on account of local

Mr. Hoad. topographical conditions, the routes taken by sewer lines are often more or less circuitous, and this constitutes another important source of irregularity with which the area has nothing to do. In the sewer map and tables accompanying the paper by W. C. Parmley, M. Am. Soc. C. E., on the Walworth Sewer at Cleveland,* the twenty-three sub-areas tributary to this sewer are shown, and the number of acres, and, also, "the number of feet from the remotest lateral to the point of discharge into Walworth Sewer" are given for each area. The ratios of these distances to the square root of the number of acres in their respective areas vary from about 100 to more than 600. Of the twenty-three areas, five give ratios of less than 250, and eight of more than 450. The mean of the largest 25% of the ratios is 2.8 times the mean of the smallest 25 per cent. The figures given neglect the relatively small distance that the storm-water must run over the surface of the ground before reaching the street inlet; but, since the variation in the ratios does not coincide with the variation in the size of the areas, this omission should not vitiate the above comparison.

Neither is the velocity of flow—the other factor of the time of concentration—entirely dependent upon the general slope of the surface, or of the sewer, or even upon a combination of the slope and the area. It is, however, chiefly determined by the slope and the quantity of water flowing, but the area is a very inaccurate measure of this latter because of the widely different degrees of imperviousness possessed by different areas. Taken on the whole, the slope, S, and the area, A, are at best only uncertain guides for the determination of the proper rainfall rate, R, to use.

The writer is strongly of the opinion that, ordinarily, it is preferable to determine the time of concentration directly in each particular area; that is, to scale the distance from a map, estimate it carefully, or measure it out on the ground, and to compute the time from this and the calculated velocity of flow, the velocity being determined with sufficient exactness from the known slopes and a preliminary estimate of the quantity of water. A more or less arbitrary addition of a few minutes should then be made to this, to allow for the time required for the water to reach the sewer. With the time, T, determined, the intensity of rainfall, I, proper for this area, should be taken from a curve or formula, the run-off factor should then be decided, and the quantity, Q, computed.

This method, of course, has been used to a considerable extent. Its chief advantages are its flexibility and its rationality. It may be used with essential accuracy on an area of any reasonable shape,

* *Transactions*, Am. Soc. C. E., Vol. LV, p. 341.

slope and size, and under any conditions of rainfall, provided that these conditions of rainfall and topography are known; if they are not known, and have to be guessed at, is at least as accurate as any of the other formulas. The advantage of a rational over an empirical method is obvious. Mr. Hoad.

The leading disadvantage that has been urged against this method is that its application is tedious and involves preliminary estimates of distance and time. This can hardly be considered a serious objection, however, as the small amount of extra office work is quite insignificant when compared with the importance of an accurate determination. Moreover, the thorough knowledge of the local conditions pertaining to each area, which is a requisite to the proper use of the method, is certainly conducive to more intelligent design. Probably a more frequent, though less recognized, obstacle is the fact that the use of the method requires a knowledge of the local rainfall curve. In case very little is known of the local rainfall rates, other than those for a 1-hour period or longer, it is much easier to shift the whole responsibility to some formula that does concern itself with variations in the rainfall rate.

The writer has developed for himself a method of using the rational formula which avoids some of the disadvantages mentioned, and which may be of some benefit to others.

The general formula, as usually stated, is:

$$Q = ACI \quad \ldots\ldots\ldots\

Mr. Hoad. meteorological conditions, and also to exclude very high rates of rainfall of infrequent occurrence.

The relation between the intensity of rainfall and the duration of the downpour—in other words, the rainfall curve—varies in different sections of the country; moreover, even in the same section, different engineers will place different valuations upon the importance of providing for the less frequent rates. It may, indeed, be entirely appropriate in a single city to design one sewer to provide adequately for the heaviest storm of a generation, and at the same time design others with such capacity that they may be expected to be surcharged every year or two. These variations in the rainfall curve may be expressed with essential accuracy by a coefficient. Owing to the manner in which precipitation records have been reported, data regarding the maximum rate lasting for 1 hour, in different localities, are more commonly available than those for any other periods, and probably most engineers have a much more accurate idea of the ordinary maximum hourly rate for their own localities and of the frequency of its occurrence than of the rates for shorter periods of time. It is believed, therefore, that a coefficient based on the rate of rainfall lasting for 1 hour may be easily and accurately applied. The rainfall curve given in Equation 2 may then be written

$$I = R \frac{80}{20 + T} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

in which

R = the maximum rate of rainfall which it is deemed expedient to consider, and lasting for the period of 1 hour.

The value of R, in the writer's curve, is 2. If it be taken as 1.5, the curve will be identical with that of Mr. Kuichling, shown in Fig. 1.*

Calling Q' the run-off, in cubic feet per second per acre, and substituting $R \frac{80}{20 + T}$ for I, Equation 1 may be written

$$Q' = C R \frac{80}{20 + T} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

which is the writer's run-off formula.

In this equation, R will probably vary for different localities and conditions from as low as 1.0 to 2.5, or perhaps more, and C may range all the way from 0.10 to nearly if not quite 1.00; this will give RC a range of from perhaps 0.20 to 2.00, as outside values. In Fig. 13 curves are drawn for this equation giving the run-off, in cubic feet per second per acre, for varying periods of time, and

Proceedings, Am. Soc. C. E., for November, 1906, p. 910.

Fig. 13.

Mr. Hoad.

FIG. 13.

Mr. Hoad. for values of RC varying by tenths from 0.20 to 2.00. The use of diagrams of this kind is to be recommended, as it not only saves time, but, which is of much greater importance, also enables the user to see something of the significance of the assumptions which he perforce must make in any calculation of run-off.

The derivation of the time, T, may be somewhat tedious, but the determination of this factor with essential accuracy is believed to be of sufficient importance to warrant the expenditure of the small amount of time necessary for it. The method already used by Mr. Parmley and others, and suggested by Mr. Gregory, of computing the actual time of flow in the tributary sewers, the length, grade and (approximate) quantity of water being previously known, and of adding to this an allowance of a few minutes for the time required for the water to reach the inlet, is certainly to be recommended. Even if these data are not available, as in the case of areas only partially sewered, they may be estimated with as much accuracy as the "average" slope, S, which is somewhat indefinite.

As a help in determining the time, T, Table 13 is given. This shows the velocities, in feet per minute, when "flowing full" in circular sewers from 18 in. to 10 ft. in diameter, on grades of from 1 to 40 per 1 000. They are adapted from a table computed from Kutter's formula, in which n has a value of 0.015.

TABLE 13.—Velocities, in Feet per Minute, in Sewers Flowing Full. From Kutter's Formula, with $n = 0.015$.

S	Diameter of Sewer, in Feet.									
	1.5	2	2.5	3	3.5	4	5	6	8	10
	Diameter of Sewer, in Inches.									
	18	24	30	36	42	48	60	72	96	120
1	90	110	130	150	170	190	220	250	300	350
2	130	160	190	220	240	270	310	350	430	490
4	190	230	270	310	350	380	440	500	600	700
6	230	280	330	380	430	460	540	610	740	860
8	260	330	380	440	490	540	620	710	860	990
10	300	370	430	490	540	600	700	790	960	1 100
15	360	450	520	600	660	730	850	970	1 160	.....
20	420	520	600	690	770	850	990	1 120	.....	.....
25	470	580	680	780	860	940	1 110	.....	.....	.....
30	510	630	740	850	950	1 040	.....	.....	.....	.....
35	550	680	800	920	1 020	1 120	.....	.....	.....	.....
40	590	720	850	980	1 090	.....	.....	.....	.....	.....

Mr. Hoad.

The manner of using the diagrams, then, is first to determine as nearly as practicable the time of concentration, T; then, from the diagram, take out the run-off, in cubic feet per second per acre, corresponding to this time and to the value of RC previously decided upon; then multiply this by the area in acres.

For the purpose of a comparison with the formulas given in Mr. Gregory's Table 4, the writer has computed Table 14, which

TABLE 14.—RESULTS OF USE OF RUN-OFF FORMULA,

$$Q' = C R \frac{80}{20 + T}$$

FOR THE AREAS AND SLOPES INDICATED.

	10 ACRES.		100 ACRES.		1 000 ACRES.		10 000 ACRES.	
	$S = 1$	$S = 10$	$S = 1$	$S = 10$	$S = 1$	$S = 10$	$S = 1$	$S = 10$
Average velocity of water, in feet per minute	120	300	160	420	220	580	300	780
T, after adding 8 min.	20	.....	36	.....	72	.....	156	.....
T, after adding 5 min.	.....	10	.....	16	.....	29	.....	62
Q, when $R = 0.80$, and $C = 0.50$	8	11	57	90	350	650	1 820	3 900
Q, when $R = 1.50$, and $C = 0.50$	15	20	107	167	650	1 220	3 410	7 320

gives similar values for the formula just developed. The distances were estimated at $443 \sqrt{A}$, the areas being twice as long as broad, and the velocities were assumed as indicated. Arbitrary additions of 8 min. in the case of the 1 to 1 000 slope, and of 5 min. in that of the 10 to 1 000 slope, were made in order to allow time for the water to reach the sewer. In order to make the run-off for 100 acres with the 10 to 1 000 slope equal to 90, and thus fulfill the conditions required of the other formulas, R was put equal to 0.80, certainly a lower value than should ordinarily be assumed in practice. In the lower part of the table are given similarly computed quantities for a value of $R = 1.5$, C remaining the same, which probably more nearly represent average conditions than those above.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the Volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

FREEMAN CLARKE COFFIN, M. Am. Soc. C. E.*

DIED NOVEMBER 11TH, 1906.

Freeman Clarke Coffin was born in Boston, on September 14th, 1856. He was the son of Alonzo King and Mary E. Coffin. His early life was spent in Patten, Maine, where he attended the public schools up to the age of fourteen years, when the support of the family fell upon his shoulders, and it became necessary for him to go into business. For a year or two he served in a general store, and then began the manufacture of furniture in a small way. In the next ten years he built up the largest establishment of its kind in the town.

Dissatisfied with the outlook for the future, he moved to Boston, at the age of twenty-six, entered the works of the Coffin Valve Company, and two years later the office of the late M. M. Tidd, M. Am. Soc. C. E., one of the leading civil engineers of New England, who was devoting himself largely to water-works construction. There Mr. Coffin began his technical studies, and laid the foundation for his future success.

In 1894 Mr. Coffin opened his own office in Boston, and in 1905 took into partnership his principal assistant, Mr. Lewis D. Thorpe.

Notwithstanding the character of his early training, and the fact that he did not take up engineering work until middle life, by dint of hard work and constant application, Mr. Coffin, in the course of a comparatively short professional career, made an enviable name for himself among the foremost engineers of New England. His professional work was largely along the lines of water-works and sewerage construction, though he was often consulted and had testified many times in water-works valuation and water diversion cases in different parts of the country.

Mr. Coffin was a Member of the Boston Society of Civil Engineers, the Canadian Society of Civil Engineers, the New England Water Works Association, and the Twentieth Century Club, of Boston. At the time of his death, he was a Vice-President of the Boston Society of Civil Engineers, and Chairman of the Sanitary Section of that Society (for the formation of which Section he

* Memoir prepared by Leonard Metcalf, M. Am. Soc. C. E., and William S. Johnson, Assoc. M. Am. Soc. C. E.

was largely responsible), and had been nominated as a Vice-President of the New England Water Works Association.

Mr. Coffin's keen interest in the technical side of his profession, and in the work of the engineering societies, is attested by the admirable papers and discussions which came from his pen. Among these might be mentioned his discussions before this Society on papers upon "The Financial Management of Water Works" and "The Valuation of Water Works Property," and his papers before the New England Water Works Association upon "The Financial Management of Water Works;" "Standpipes and Their Design;" "Friction in Several Pumping Mains;" "Corrosion of Pipes;" "Application of Gas, Gasoline and Oil Engines to Pumping Machinery," and "Covered Reservoirs and Their Design."

One of the most notable of his services to the engineering profession grew out of his paper presented before the New England Water Works Association, containing "A Few Notes on Cast-Iron Pipe," which led to his appointment as Chairman of the Committee of that Society which drafted the "Standard Specifications for Cast Iron Pipe and Special Castings." These specifications have been substantially adopted by the American Water Works Association, and are now coming into general use. Mr. Coffin also published a handbook entitled "Graphical Solution of Hydraulic Problems" which has won favorable comment, and has passed through two editions.

He died at his home in West Medford, on November 11th, 1906, leaving a wife and four sons.

While the demands of his professional practice prevented Mr. Coffin from attending the meetings of this Society to any great extent, he took a very active interest in the affairs of the local societies, and was widely and very favorably known professionally throughout New England, and in the adjoining States and Provinces. Studious in mind, honest in conviction, and courteous in manner, Mr. Coffin won for himself the respect and confidence of all with whom he came in contact. In his death the profession loses an able and clear-headed thinker; the community, an honest and public-spirited man.

Mr. Coffin was elected a Member of the American Society of Civil Engineers on February 6th, 1895.

WALLACE CLYDE JOHNSON, M. Am. Soc. C. E.

DIED DECEMBER 15TH, 1906.

Wallace Clyde Johnson was born in Granville, Massachusetts, on May 21st, 1859. He was a son of James W. and Frances A. Johnson. Mr. Johnson was educated in the public schools of his native town, and in the years 1880-82 attended Williams College. In 1884 he was graduated from the Worcester Polytechnic Institute, and in the same year he accepted a position with the Holyoke Water Power Company, of Holyoke, Massachusetts, as Assistant Engineer. While occuping this position, his ability, energy and engineering skill commanded attention. When Clemens Herschel, M. Am. Soc. C. E., of Holyoke, was requested to recommend an engineer to take charge of the development of the Niagara Falls Hydraulic Power and Manufacturing Company, at Niagara Falls, New York, Wallace C. Johnson was the man recommended.

This was in 1886, and it requires but a casual review of the hydro-electric conditions in the United States to understand fully what this recommendation meant. The period since then has been one of truly wonderful accomplishments in the hydro-electric development of the world.

Mr. Johnson remained Chief Engineer of the Niagara Falls Hydraulic Power and Manufacturing Company until 1900, at which time he became the Consulting Engineer, which position he held until his death. While he was Chief Engineer of that company he designed and had executed, under his supervision, the hydro-electric development of this Company on the banks of the Lower Niagara River, this being the pioneer hydro-electric development of the country, using turbines under a head of more than 200 ft. This plant, as well as many others which he designed, will stand as monuments to his memory.

In 1900 Mr. Johnson accepted the position of Chief Engineer of the Shawinigan Water and Power Company. He designed their plant at Shawinigan Falls, Quebec, Canada, which is the largest water-power development in the Dominion. The water-wheels used in this plant were, at the time of their installation, the largest ever built, and the transmission line from Shawinigan Falls to Montreal was the longest east of the Rocky Mountains.

On June 11th, 1906, Governor Higgins appointed him a member of the State Water Supply Commission, and the broad field of the Commission was particularly interesting to a man of his attainments.

Mr. Johnson's advice was continually sought by companies contemplating water-power development and by those desiring to re-

model or enlarge plants already built. He made examinations and reports on water-power propositions covering the United States from Maine to California, throughout the Dominion of Canada, and in Nicaragua.

He held the position of Chief and Consulting Engineer of the Niagara Falls Hydraulic Power and Manufacturing Company, at Niagara Falls, New York; Chief and Consulting Engineer of the Shawinigan Water and Power Company, at Shawinigan Falls, Quebec; Chief and Consulting Engineer of the Bodwell Water Power Company, at Old Town, Maine; Chief and Consulting Engineer of the Hannawa Falls Water Power Company, St. Lawrence County, New York; Chief Engineer of the Empire State Power Company, Chief Engineer of the Chicoutimi Power Company, Quebec; and Chief Engineer and General Manager of the Albion Power Company, Albion, New York.

Mr. Johnson's genial disposition and cordial manner made him a great favorite. He was a member of the American Society of Mechanical Engineers, and of the Engineers Society of Western New York, of which society he was Past-President. He was also a Member of the Canadian Society of Civil Engineers; and an Associate Member of the American Institute of Electrical Engineers; and of the Society of Arts, London, England. He was a member of the St. James Club, of Montreal; the University Club, of Buffalo; and the Tarratine Club, of Bangor, Maine.

On May 31st, 1893, he was married to Miss Eloise Gertrude Murlless, of Holyoke, Massachusetts, who survives him.

Mr. Johnson died at the comparatively early age of forty-seven years, but the work which he accomplished bears testimony to the active life he led. He was constantly and effectively in the field of work, and his life was devoted to his profession. His services were highly valued by the various companies with which he was connected.

Mr. Johnson was elected a Member of the American Society of Civil Engineers on October 5th, 1892.

GEORGE TATNALL, M. Am. Soc. C. E.*

DIED SEPTEMBER 13TH, 1906.

George Tatnall was born in Wilmington, Delaware, on December 27th, 1853. His father was Edward Tatnall, and his mother, Rachel Richards Webb; his grandparents were Edward Tatnall and Margery Paxson, James Webb and Lydia Pritchett Richards. He

* Memoir prepared by William A. Pratt, M. Am. Soc. C. E.

came of good old Quaker stock, his ancestors on both sides having been members of the Society of Friends, in England, before coming to America.

The first Tatnall came to Wilmington from Leicestershire, England, in 1725. The early Webbs, Pritchetts, Lamborns, and Richards came from England to Chester County, Pennsylvania, at various times between 1685 and 1700, the immediate ancestors of Mr. Tatnall subsequently moving to Wilmington. His grandfather, James Webb, started the first morocco tannery, and this has since become the leading industry in Wilmington. He was a Member of the City Council, and of the Board of Education, and was an ardent anti-slavery advocate.

Mr. Tatnall received his early education at the Friends School, Wilmington, and was fitted for college at T. Clarkson Taylor's Academy. In 1870-71 he was a student in the engineering course, Cornell University. Leaving college at the end of this session, he became a Rodman on the construction of the Wilmington and Western Railroad. During 1872, and part of 1873, he was Assistant Division Engineer for ten months under J. Dutton Steel on the Berks County Railroad, and then Division Engineer on the same road from Maiden Creek to Lenhart.

In September, 1873, he returned to Cornell University and in June, 1875, took the degree of B.C.E., completing the four years' course in three years. On leaving the University he obtained a position with Cofrode and Taylor, of Philadelphia, remaining a year with them, bridge drafting and designing some of the minor buildings of the Philadelphia Centennial Exposition. For the next year he was engaged at the Edgemoor Bridge Works and in private practice. From 1877 he was Topographer on Location and Assistant Engineer on Construction on the Pittsburg and Lake Erie Railroad, on the Division of the Ohio River Bridge at Beaver, and the terminal under the Pittsburg, Fort Wayne and Chicago Railroad, at Beaver Falls, Pennsylvania. On the completion of this work he went the Mexico as Principal Assistant Engineer for an American syndicate to locate and construct the Vera Cruz, Anton Lizards and Alvarado Railroad. After a few months the American company withdrew from the work, and he remained as Consulting Engineer with the Mexican company until December, 1879. After engaging in private practice for several months, he was, in September, 1880, appointed Assistant Engineer of the Philadelphia, Wilmington and Baltimore Railroad, and, when the Pennsylvania Railroad acquired this property, he remained in the service of this road until 1904, a record of 24 years, during which time he was engaged in designing and erecting wooden and iron highway and railroad bridges, in preliminary and location surveys, and in the

construction of branch roads, of third and fourth track, yards and sidings, freight houses, grain elevators, cold-storage houses, and other heavy buildings, notably the Quaker City Cold Storage Building, and the Philadelphia Market House.

In 1904 he left the Pennsylvania Railroad to engage in consulting practice in Philadelphia, and in 1905 was appointed Principal Assistant Engineer of the New York, Westchester and Boston Railway, locating and building a high-speed four-track electric railway in the Borough of the Bronx, New York City, and in Westchester County, New York, which position he held at the time of his death.

On September 12th, 1900, he was married to Catherin Jewett Coolidge, of Wayland, Massachusetts, daughter of James Coolidge and Henrietta A. Saunders, both of Salem, Massachusetts. His wife and two sons and a daughter survive him.

In 1905 he became interested in a new explosive, called Ferronite, invented by Franz Wartenberger, with which the inventor had been allowed to experiment on the railway with which Mr. Tatnall was connected. Mr. Tatnall, while visiting his wife's family, at Wayland, Massachusetts, was induced by Wartenberger to go to Lynn, on September 7th, to witness a demonstration he was to give some contractors at a quarry at that place. While Wartenberger was loading a hole, Tatnall thought he was doing it in a careless manner, and started to remonstrate, when a premature explosion occurred, terribly injuring both. His first thought, in spite of his own suffering, was for others, and, calling to the spectators to stand back, he tried to extinguish the burning clothes of his companion, and, on the arrival of the ambulance, insisted that Wartenberger should be attended to first. They were both hurried to the Lynn Hospital, but Wartenberger died soon after being admitted.

Mr. Tatnall displayed wonderful vitality, recovering from the shock, and at times giving hope that he might recover. He lingered five days, dying of hemorrhage from a ruptured artery at 6 A. M. on September 13th, 1906. His wife and two sisters were able to reach him and attend his last hours.

Mr. Tatnall possessed all the sterling qualities of his Quaker ancestors; he was of high personal character, genial with his associates, and devoted to his family.

He was an engineer of ability, painstaking and thorough in his work, and always considerate of others, and leaves a host of friends who deeply mourn his untimely death.

He was elected a member of the American Society of Civil Engineers on May 3d, 1899; and was also a member of the Transportation Club, to which he had contributed several papers.

ARTHUR PRICE LAW, Assoc. M. Am. Soc. C. E.*

DIED NOVEMBER 19TH, 1906.

Arthur Price Law, Superintendent of Construction for the Holbrook, Cabot and Rollins Corporation, died at his home in East Providence, Rhode Island, on Monday, November 19th, 1906, of typhoid fever.

Mr. Law was born in New York City on July 7th, 1870, and attended the public schools and high school in Flushing, Long Island, and was a graduate from the full civil engineering course of the International Correspondence Schools, of Scranton, Pennsylvania.

He worked as assistant on Government surveys in Florida, and in 1893 was engaged by the New York, New Haven and Hartford Railroad Company, on heavy construction, making a specialty of bridge foundations. He stayed with this company as Junior and Senior Assistant Engineer until 1900, when he entered the service of Holbrook, Calbot and Rollins, as Superintendent of Construction, in charge of deep foundations and substructure work, and was in their employ at the time of his death.

During the seven years of his connection with the Holbrook, Cabot and Rollins Corporation he had charge for them of the foundations for a double-track railroad bridge at Tiverton, Rhode Island, and all the work at Bridgeport, Connecticut, done by this corporation. He started the work on the Housatonic River foundations, and then went to the Connecticut River and completed the work on the deep foundations there. Later, he took up the matter of the foundations for the work at Neponset, Massachusetts, and also for the bridge across the Seekonk River at Providence, Rhode Island. All this work was done for the New York, New Haven and Hartford Railroad Company.

His work was carried through with marked ability and success, and without any trouble or loss either to the Railroad Company or the Holbrook, Cabot and Rollins Corporation, and was done to the utmost satisfaction of both these corporations.

Mr. Law belonged to the Red Men, and was elected an Associate Member of the American Society of Civil Engineers on June 3d, 1903.

* Memoir prepared by J. W. Rollins, Jr., M. Am. Soc. C. E.

HENRY BRIGHAM LOOKER, Assoc. M. Am. Soc. C. E.*

DIED JANUARY 3D, 1905.

Henry Brigham Looker was born in Cincinnati, Ohio, on April 10th, 1858. He was the eldest son of former Paymaster-General Thomas H. Looker, United States Navy, and was of a family which had been for several generations represented in the military and naval forces of the United States, from the time of Othniel Looker, who served as private in Colonel Martin's Regiment of the Jersey Line in 1776, and in other Revolutionary organizations until 1782. Aside, however, from three years' service as a cadet at the United States Military Academy and six months' service as Captain of Volunteers during the Spanish War, Major Looker devoted himself to civil engineering and surveying until his untimely death, which was undoubtedly hastened by the hardships of this short military service.

Major Looker was educated in part at the Maryland Agricultural College, in part at the United States Military Academy at West Point, and in part by private tutors. Leaving West Point in 1881, he began active engineering practice with a year's service in a subordinate capacity on the surveys for the Delaware and Chesapeake Ship Canal, and for the Lockport Tunnel, and Relocation Work for the Lehigh Valley Railroad. From September, 1882, until June, 1887, he was engaged in work of instruction in mathematics, surveying, military engineering, and tactics at the Bettz Military Academy at Stamford, Connecticut, and at De Veaux College, Suspension Bridge, New York. In June, 1887, he entered the office of General Herman K. Viele, Civil and Topographical Engineer, Washington, D. C., as Principal Assistant in charge of field and office work relating to surveys, landscape engineering, electric railroads, subdividing and grading suburban land, and general municipal practice. In July, 1890, he opened an office for himself as a civil engineer, working along these and similar lines, and during the five succeeding years, in work of this nature covering the entire District of Columbia, established himself as one of the leading engineers in private practice at the Capital. In March, 1895, at the instance of the leading business men of Washington, he was appointed Assistant Surveyor of the District of Columbia, and in August, 1897, he succeeded Mr. William Forsyth as Surveyor, which office he held until his death, except as noted below.

At the outbreak of the Spanish War he volunteered for service, and was appointed Major in the Brigade of the National Guard of the District of Columbia. As the quota of the United States

* Memoir prepared by Jay J. Morrow, M. Am. Soc. C. E., Captain, Corps of Engineers, U. S. Army.

Volunteer troops from the District was reduced from a brigade to a regiment, he accepted the appointment as Captain of Company H, which was detached to serve as engineers in General Miles' expedition to Porto Rico. He resigned his office of Surveyor of the District of Columbia, to accept this commission, on July 7th, 1898. The company rendered important service at the landing near Guanica, and on July 25th, 1898, captured the first Spanish flag taken in Porto Rico. The company constructed several military bridges in Porto Rico, and, as part of a provisional battalion of engineers, built the road leading to Fort Capron. Major Looker was temporarily appointed Military Governor over one of the military districts of Porto Rico, and served in this quasi-civil capacity with credit. He received honorable mention in reports to the War Department, and his name was included in the list of nominations by the President for brevets, all of which failed of confirmation by the Senate. At the close of the war he was presented with a handsome sword, by the men of his command, as a testimonial of their affection and esteem.

After being honorably discharged from the military service of the United States, Major Looker was reappointed Surveyor of the District of Columbia on November 22d, 1898, which office he held until his untimely death, January 3d, 1905. During the last year of his life it became evident that the exposures incident to the tropical campaign had affected his health, but so sudden a termination was not anticipated, his death coming suddenly and resulting from congestion of the brain. Upon the announcement of his death, his valuable public services, his sterling integrity of character, and the noble Christian virtues practiced by him in life, were recognized publicly by the Commissioners of the District of Columbia through the issuance of the resolutions herewith quoted:

"*Whereas,* The Commissioners of the District of Columbia have learned with deep regret of the death of Henry B. Looker, late Surveyor of the District of Columbia, who died at 3:20 A. M., January 3d, 1905.

"*Resolved:* That the Commissioners of the District of Columbia hereby testify their appreciation of the services rendered by the deceased during his incumbency of the office of Surveyor of the District of Columbia, which extended from August 18th, 1897, to the day of his death without interruption except between July 7th, 1898, and November 22d, 1898, during which time Mr. Looker commanded a company which took part in the Spanish-American War. Mr. Looker was a man of sterling integrity, and eminently qualified to hold the responsible position which he occupied, and his death is a loss to the District of Columbia.

"*Resolved:* That a copy of this resolution be entered on the minutes of the Board of Commissioners, a copy be sent to the relatives of the deceased, and copies be furnished the daily press."

Major Looker was married in 1893 to Miss Catherine Earle, and is survived by her and by one son.

He was elected an Associate Member of the American Society of Civil Engineers on May 3d, 1893.

EDDY ELBERT YOUNG, Assoc. M. Am. Soc. C. E.*

DIED JUNE 1ST, 1906.

Eddy Elbert Young was born at Wapun, Wisconsin, on January 4th, 1865. His parents were Enoch and Cordelia Young. When he was two years old his parents removed to Lowell, Massachusetts, in which city his boyhood was passed.

He commenced work at the early age of sixteen, having then gone through only part of the course at the Lowell High School. After leaving school, however, he continued his studies, taking up mechanical and architectural drawing in evening classes for several years. Later in life he often expressed regret at leaving school so soon, although his associates considered this regret as needless, for, by his private study and his close and accurate observation, he became in many respects a man of culture as well as an advancing engineer. At the time of his early death he had done much good work, and the indications were that he would do even better.

The following is a brief summary of his professional career, but it is incomplete in that it gives no indication of the generally excellent character of his work.

In the spring and summer of 1881 Mr. Young was a Draftsman and Rodman for the Merrimack Manufacturing Company, on mill engineering. From May, 1883, to April, 1884, he was a Draftsman and Rodman with Melvin B. Smith, Civil Engineer and Surveyor; for the remainder of 1884 he served as a Draftsman and Transitman on short engagements of a miscellaneous character. From March, 1886, to May, 1888, he served as Draftsman and Transitman on the New York and New England Railroad, and from September, 1888, to March, 1889, in a similar capacity, and also as Inspector, for the Boston and Maine Railroad on the construction of the Mystic Terminal Grounds.

During the summer of 1889 Mr. Young was an assistant with George H. Barney, Civil Engineer and Surveyor, at Hyde Park, Massachusetts; and from the autumn of 1889 to the spring of 1890 was an assistant and inspector with Percy M. Blake, Civil Engineer, on the construction of the water-works at Andover, Massachusetts. During the spring and summer of 1890, under the late

* Memoir prepared by Howard A. Carson, M. Am. Soc. C. E.

Albert F. Noyes, M. Am. Soc. C. E., City Engineer of Newton, Massachusetts, he was an assistant on assessor's maps, drafting, surveying, computing, etc.

In September, 1890, he entered the service of the Metropolitan Sewerage Commission, as Draftsman and Transitman, and was engaged in the office and on the surveys and construction of the North Metropolitan and Charles River Systems, including tunnel work under compressed air. In October, 1894, he left the employ of the Metropolitan Sewerage Commission, and entered that of the Boston Transit Commission, as Assistant Engineer, where he remained until March, 1898. During this period he was engaged on the construction of the Boston subways, designs for ventilating chambers, grading and sewers for Boston Common, tunnels under thoroughfares, and pile foundations for the Public Garden incline. From April, 1898, to January, 1899, he was Assistant Engineer on sewer assessments in Boston, and from February to April, 1899, Assistant Engineer on designs for masonry structures for the Boston Elevated Railway.

In June, 1899, Mr. Young again entered the service of the Metropolitan Sewerage Commission, as Assistant Engineer, and, until August, 1903, was engaged on surveys and construction of the high-level sewer, involving tunnel work in earth and rock, and the use of compressed air in advancing the headings through quicksand.

In August, 1903, he entered the employ of Messrs. Jacobs and Davies, Consulting Engineers, as Engineer of Alignment on the Hudson Tunnel, having charge of the triangulation, lines, grades, etc. From August, 1904, until January 31st, 1906, he was in charge of drafting for the O'Rourke Engineering Construction Company, and from February 1st, 1906, until his death he was Engineer and Manager of the New York work of the Healey Sewer Machine and Construction Company, which company was engaged in land and subaqueous borings for various railroads, the New York Rapid Transit Railroad Commission, and for the additional water supply for New York City.

As an indication that Mr. Young's work was excellent in character, he was given a bonus of $500 by his employers, Messrs. Jacobs and Davies, on the meeting of the headings of the Hudson River Tunnel, for the alignment of which he had been responsible. In the letter of transmittal, which also informed him of an increase in salary, this bonus was mentioned as "some appreciation" of the value of his work and of the untiring energy with which he had always devoted himself to the interests of the tunnel company.

On February 6th, 1897, he was married to Miss Alice Frances Carter, of Charlestown, Massachusetts, who, with two children, survives him.

For some years prior to his death, Mr. Young's physical condition had been such as to call for a surgical operation of a serious nature. His very energy and ambition here worked against him, leading him to delay too long in seeking surgical relief; however, in April, 1906, he went to Boston, where, in a private hospital, the necessary operation was performed, on the 6th of that month. On April 25th he went back to work in New York, but two days later was forced to give up. He returned to his home in Auburndale, and died there on June 1st, 1906. The immediate cause of his death was acute nephritis, but the original cause was his unselfish devotion to work, which led him to forget himself too completely. He was buried in Lowell, Massachusetts.

Mr. Young's fondness for music, his talent for drawing and modeling, and his appreciation of the beautiful in form and color, indicated his fine taste.

Many will feel that by his death they have lost a valued friend, and the engineering profession an ambitious member who was earnest in whatever he undertook, doing all his work honestly, truthfully and well.

Mr. Young was elected an Associate Member of the American Society of Civil Engineers on January 6th, 1904.

ALBERT HENRY ZELLER, Assoc. M. Am. Soc. C. E.*

DIED NOVEMBER 2D, 1906.

Albert Henry Zeller was born in St. Louis on January 20th, 1867. He was the second son of William Zeller and Christine Haarstick-Zeller. His death occurred in St. Louis on November 2d, 1906, after an illness of several months. He is survived by his mother, two brothers, William F. and Eugene C. Zeller, and one sister, Mrs. F. W. Frerichs, of St. Louis.

When he was three years old his parents took him to Germany for a year, returning to America in 1871. At this early age he developed a love for music, and was allowed to begin his studies on the violin. In later years, without permitting his love for music to encroach upon the time due his chosen profession, that of Civil Engineering, he devoted many of his leisure hours to the violin, to his own enjoyment and that of a few chosen friends.

Mr. Zeller received his early education at the St. Louis public schools, attending the Peabody School at St. Louis from 1873 until 1878, when he was sent to a French school at Lausanne, Switzer-

* Memoir prepared by Edward Flad, E. B. Fay and W. G. Brenneke, Members, Am. Soc. C. E.

land. He remained at Lausanne two years, taking a regular course, but devoting considerable time to the study of the French language, in which he became very proficient.

In 1880 he returned to St. Louis and attended Smith Academy, and later Washington University. He was graduated from the former in 1883 and from the latter in 1887, with the degree of Bachelor of Engineering.

He was particularly fond of mathematics, and was ever ready to apply mathematical solutions to problems coming under his notice.

Mr. Zeller's first employment after graduation was as Draftsman and Assistant Engineer on the St. Louis, Iron Mountain and Southern Railway, at St. Louis, where he remained until April, 1889. From April, 1889, until May, 1891 (with the exception of the period from May to December, 1890, during which time he traveled in Europe), he was engaged as Assistant Engineer with the St. Louis Merchants Bridge Terminal Railway, St. Louis, Robert Moore, Past-President, Am. Soc. C. E., Chief Engineer. From May, 1891, to November, 1892, he was employed in the designing department of the Edge Moor Bridge Works, Wilmington, Delaware. From February to May, 1893, he was Principal Assistant Engineer of the St. Louis Terminal Railway Association, in charge of the erection of the train-shed at the new Union Station. In May, 1893, he was appointed Engineer Assistant to the President of the Board of Public Improvements, at St. Louis, a position which he filled for four years with much credit to himself and much profit to the city. Robert McMath, M. Am. Soc. C. E., who was President of the Board of Public Improvements at the time, in writing of Mr. Zeller, states:

"He declined reappointment for another term, intending to go to Europe for a long stay. I was sorry to lose him, for he was worthy of confidence, and our relations were wholly pleasant to both, as were his relations with all who came in contact with him."

Resigning from the service of the city in 1897, he went abroad for two years; on his return, he opened an office at St. Louis for the general practice of his profession, at which work he was engaged at the time of his death.

For some years past, however, he had devoted much of his time to managing the estate of his family; and, though he kept abreast of the time in his profession, and was well posted on the engineering problems of the day, he did not engage in extensive practice.

Mr. Zeller had traveled much, having visited Europe five times. He was a man of broad mind and sound judgment, and without

guile or deceit. To know him was to admire him. Justice and truth and gentleness were embodied in his every act and thought. His friends thought of him as one on whom they could depend for assistance in every good cause, and, if need be, for such sacrifices as friendship calls for.

In his untimely death the engineering profession has lost a member whose life could ill be spared. The community in which he lived, and the associates who enjoyed his friendship will remember him and continue to feel the influence of his thought and his life, and he will not have lived in vain.

It seems but proper to add the following testimonial by Mr. William Chauvenet:

"How pleasant it is—after all—to speak of one whose memory must ever be a sweet one and whose life as we recall it will ever help to make us better men.

"It was his gentleness in all his relationships, and his justice in all dealings with men, that most impressed me. He was strong to see the right and fitting thing to be done in any emergency, and his clear vision was ever helpful to his friends.

"His command of himself in all positions, and the absence of any tinge of severity in the exhibition of such command, was one of his most noted characteristics.

"Ever considerate of others, he nevertheless made you feel that he was somehow under obligations to the one he was helping, and this mark of the true gentleman was one of his charms as a companion and as a friend.

"Of his own fortunes, whether good or bad, he never spoke, while his ever-active interest in the good fortunes of others, and his sure sympathy in times of loss, made him one whom we naturally sought out whenever the clouds hung low.

"Assuming nothing, yet was his judgment sound, and in all his relationships with men, and especially with his comrades, nothing could disturb his sweetness.

"I know I am naming the characteristics of a rare man, and one more associated with the 'old school' than with our aggressive and unconventional times, yet such was my friend and dear companion.

"He is to me alive and often present in our midst, because his qualities partook of those things which do not die, but live on, safe within the hearts of those who had learned to love him while here."

He was a member of the Engineers' Club of St. Louis, the University Club, and St. Louis Field Club. He was elected a Junior of the American Society of Civil Engineers on May 7th, 1890, and an Associate Member on April 7th, 1897.

BENNO ROHNERT, Jun., Am. Soc. C. E.*

DIED SEPTEMBER 1ST, 1906.

Benno Rohnert was born at Detroit, Michigan, on September 10th, 1866, and died at North Bay, Ontario, on September 1st, 1906.

He received his education in the public schools of Detroit and in the University of Michigan, being graduated from the Detroit High School in 1883, and from the Civil Engineering Department of the University of Michigan in 1887. While at the University, he was one of the leaders in his class, and during his senior year he was Managing Editor of *The Chronicle*, one of the University publications.

From 1887 to 1889, Mr. Rohnert was Assistant to F. Collingwood, M. Am. Soc. C. E., in the construction of the Dry Dock at Newport News, Virginia. In 1889, he was appointed by General O. M. Poe, Corps of Engineers, U. S. A., as Assistant to E. S. Wheeler, M. Am. Soc. C. E., on the public work of improvement in St. Marys River, and for fifteen years he was identified with this work in various positions of responsibility. He did all the instrument work connected with the construction of the Poe Lock, at Sault Ste. Marie, Michigan; and later, as Assistant to Joseph Ripley, M. Am. Soc. C. E., he had responsible charge of the work of making surveys for the purpose of channel improvements in St. Marys River, covering a length of channel of about 50 miles and involving the expenditure of from $6 000 000 to $8 000 000. A part of his duty, as Assistant to Mr. Ripley, was the making of all surveys, measurements, and estimates leading up to the improvement of the West Neebish Channel in St. Marys River, now under construction at a cost of about $4 500 000. Since 1904, he was engaged in private practice until his sudden death by apoplexy.

Mr. Rohnert was an active member of the Masonic fraternity and a Knight Templar. Among his associates, both business and social, he was known for his honesty and stanch integrity; and he held his friends by his genial, broad-minded, and tolerant disposition. He was elected a Junior of the American Society of Civil Engineers on April 3d, 1889.

* Memoir prepared by Charles Y. Dixon, M. Am. Soc. C. E.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

(INSTITUTED 1852.)

VOL. XXXIII. No. 3.

MARCH, 1907.

Edited by the Secretary, under the direction of the Committee on Publications.

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NEW YORK 1907.

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American Society of Civil Engineers

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ON STATUS OF METRIC SYSTEM:—Stacy B. Opdyke, Jr., John Waterhouse, D. A. Molitor.

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

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CABLE ADDRESS....."Ceas, New York."

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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MINUTES OF MEETINGS.

OF THE SOCIETY.

February 20th, 1907.—The meeting was called to order at 8.30 P. M.; George W. Tillson, M. Am. Soc. C. E., in the chair; Chas. Warren Hunt, Secretary; and present, also, 143 members and 45 guests.

A paper by Charles Emerson Gregory, Assoc. M. Am. Soc. C. E., entitled "Rainfall, and Run-Off in Storm-Water Sewers," was presented by the author.

The Secretary announced that he had received written discussions on Mr. Gregory's paper from Messrs. William C. Hoad, A. Marston, W. B. Ruggles, Emmet A. Steece and L. J. Le Conte.

A paper by Edward Wegmann, M. Am. Soc. C. E., entitled "The Design of the New Croton Dam," was presented by the author

and illustrated with lantern slides. The paper was discussed orally by C. S. Gowen, M. Am. Soc. C. E., and the author.

The Secretary read a letter from D. Farrand Henry, M. Am. Soc. C. E., transmitting and describing some specimens of long-buried wood dug up near Detroit, Mich.

The Secretary announced the following death:

MYRON EDWARD EVANS, elected Junior January 3d, 1895; Associate Member February 7th, 1900; died February 16th, 1907.

Adjourned.

March 6th, 1907.—The meeting was called to order at 8.40 P. M.; President George H. Benzenberg in the chair; T. J. McMinn, Assistant Secretary, acting as Secretary; and present, also, 122 members and 21 guests.

The minutes of the Annual Meeting, January 16th, and of the meeting of February 6th, 1907, were approved as printed in the *Proceedings* for February, 1907.

The President appointed Messrs. W. B. Bamford, G. L. Christian, James L. Davis, William J. Boucher, and Horace J. Howe as tellers to canvass the ballot on the proposed amendments to the Constitution.

A paper by W. F. Dennis, M. Am. Soc. C. E., entitled "Uniformity of Requirement and Clearness of Specification in Agreements for the Graduation of Railroads," was presented by the Assistant Secretary, who also read written discussions from Messrs. Harold Bouton and H, P. Gillette. The paper was discussed orally by Messrs. F. Lavis and T. Kennard Thomson. Additional written discussions from Messrs. George L. Dillman, J. L. Campbell and M. S. Parker were not read owing to lack of time.

The tellers appointed to canvass the ballots on the proposed amendments to the Constitution* reported as follows:

Number of ballots received		1 294
Without signature	7	
Not entitled to vote	3	
Defective	8	
Affirmative ballots	429	
Negative ballots	847	
		1 294

An affirmative vote of two-thirds of all ballots cast being necessary for the adoption of any amendment, in accordance with Section 5, Article IX, of the Constitution, the President declared the amendment lost.

* See *Proceedings*, Vol. XXXIII, p. 71.

Ballots for membership were canvassed, and the following candidates elected:

As Members.

Percy Herbert Ashmead, New York City.
Thomas Earle, Steelton, Pa.
Harry Hugh Hadsall, Chicago, Ill.
Henry Francis Hill, Augusta, Me.
William Henri Vale Reimer, East Orange, N. J.
Frank Justus Schnauber, Syracuse, N. Y.
Christian John Wolfe, Brooklyn, N. Y.

As Associate Members.

Henry Baum Brewster, Syracuse, N. Y.
Eugene Bradford Bumsted, New York City.
Charles Cohen, New York City.
John Hugh Dodd, Kingston, Jamaica.
Albert Howard Horton, Chicago, Ill.
Sherman Augustus Jubb, San Francisco, Cal.
Robert Roy McGregor, Hazen, Nev.
Cyril Ernest Davis Marshall, Brooklyn, N. Y.
Clyde Tucker Morris, Columbus, Ohio.
Adelbert Reid Nichols, New York City.
Philip à Morley Parker, Lahore, Punjab, India.
Walther Raster, Chicago, Ill.
Arthur Adams Reimer, East Orange, N. J.
Harry Francis Sawtelle, Boston, Mass.
David Joseph Shaw, Yorktown Heights, N. Y.
Theodore Wheeler Souther, West Point, N. Y.
Eugene True Thurston, Jr., Berkeley, Cal.
Roy Dexter Tyler, Franklin, Pa.
Harry Parsons Willis, Waterford, N. Y.

As Associate.

James Roosevelt Shanley, Jersey City, N. J.

The Assistant Secretary announced:

The transfer of the following candidates by the Board of Direction, on March 5th, 1907:

From Associate Member to Member.

William Parsons Boright, Cleveland, Ohio.
Roscoe Nathaniel Clark, Hartford, Conn.
Charles Corner, Bulawayo, Rhodesia, South Africa.

Richard George Doerfling, San Francisco, Cal.
Robert Peel Garrett, St. Louis, Mo.
Frank Lynwood Garrison, Philadelphia, Pa.
William Leonard Glazier, Newport, Ky.
Glenn Dickinson Holmes, Syracuse, N. Y.
Orval Omar McReynolds, Los Angeles, Cal.
Robert Maitland Roy, Hamilton, Ont., Canada.
Richard Fenwick Thorp, London, England.
Harry Esmond Warrington, Cincinnati, Ohio.

The election of the following candidates by the Board of Direction:

As Juniors.

On October 30th, 1906:

Stanley Phister Finch, Austin, Tex.

On February 5th, 1907:

Jason Paige, Chicago, Ill.

On March 5th, 1907:

Edward Anderberg, Tonawanda, N. Y.
Olin McClintock Boyle, Jr., Greenwater, Cal.
Walter Elliott Burns, Midway, Cal.
Granville Johnson, Boston, Mass.
Irving Paul Jones, Mexico, Mexico.
Emmett Lincoln Marsh, Elkton, Ore.
Rowland Grenville Rice, Stamford, Conn.
Ross Milton Riegel, Ithaca, N. Y.
Thomas Farwell Rogers, Burlingame, Cal.
Arthur Linville Terry, Jr., Woodbury, N. J.

The Assistant Secretary announced the following deaths:

John Watson Bacon, elected Member July 12th, 1877; died February 27th, 1907.

Charles Davis, elected Member September 15th, 1869; died February 21st, 1907.

Horatio Seymour, elected Associate January 8th, 1873; Member April 7th, 1880; died February 21st, 1907.

Adjourned.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, April 3d, 1907.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper entitled "Movable Bridges," by C. C. Schneider, Past-President, Am. Soc. C. E., will be presented for discussion.

This paper was printed in *Proceedings* for February, 1907.

Wednesday, April 17th, 1907.—8.30 P. M.—At this meeting a paper entitled "The Laws of Proportioning Concrete," by William B. Fuller and Sanford E. Thompson, Members, Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings.*

Wednesday, May 1st, 1907.—8.30 P.M.—A regular business meeting will be held. Ballots for membership will be canvassed, and the Reports of the Committees on the Effects of the San Francisco Earthquake of April 18th, 1906, on Engineering Constructions, will be presented for discussion.

These reports are printed in this number of *Proceedings.*

ANNUAL CONVENTION.

The Thirty-ninth Annual Convention of the Society will be held in the City of Mexico, but the precise date has not yet been fixed; it will be held, however, between June 20th and July 20th, 1907.

The decision of the Board, to hold the Convention in the City of Mexico, is mainly due to a special invitation received from President Diaz, through his Minister of Public Works, Mr. Leandro Fernandez, who is also President of the Mexican Society of Engineers; it is also due to the fact that either free, or practically free, transportation has been promised from the United States border, not only to the City of Mexico, but also for such excursions as may be decided upon.

A committee of the Board, consisting of Messrs. A. L. Bowman, J. Waldo Smith, and the Secretary, has been appointed to take charge of all arrangements on behalf of the Board, and, as soon as the time is fixed definitely and other preliminaries are arranged, a circular will be issued for the information of the membership.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all meetings:

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Society of Engineers, 17 Victoria Street, Westminster, S. W., England.

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Civil Engineers' Club of Cleveland, 718 Caxton Building, Cleveland, Ohio.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa.

Engineers' Society of Western Pennsylvania, 803 Fulton Building, Pittsburg, Pa.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

Louisiana Engineering Society, 604 Tulane-Newcomb Building, New Orleans, La.

Engineers' Club of Central Pennsylvania, Corner Second and Walnut Streets, Harrisburg, Pa.

Engineers' and Architects' Club of Louisville, Ky., 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

Teknisk Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Société des Ingénieurs Civils de France, 19 Rue Blanche, Paris, France.

Svenska Teknologförenigen, Brunkebergstorg 18, Stockholm, Sweden.

Institute of Marine Engineers, 58 Romford Road, Stratford, London, E., England.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Pacific Northwest Society of Engineers, 617–618 Pioneer Building, Seattle, Wash.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Memphis Engineering Society, Memphis, Tenn.

Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

The Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Institution of Engineers of the River Plate, Buenos Aires, Argentine Republic.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Cleveland Institute of Engineers, Middlesbrough, England.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Rochester Engineering Society, Rochester, N. Y.

Brooklyn Engineers' Club, 197 Montague Street, Brooklyn, N. Y.

SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

In reference to this work, a summary of all searches made to date will be found in the Appendix* to the Annual Report of the Board of Direction for the year ending December 31st, 1906.

* *Proceedings*, Vol. XXXIII, p. 20 (January, 1907).

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

San Francisco, Cal.

(Abstract.)

February 15th, 1907.—The eleventh regular meeting of the San Francisco Association of Members, Am. Soc. C. E., was held; A. L. Adams, President, in the chair; Franklin Riffle, Secretary; and present, also, 27 members and 6 guests.

The minutes of the previous meeting were read and approved.

The President discussed, orally, certain factors entering into the problem of determining the economic diameters of pipes used in delivering water for power purposes, illustrating his remarks with diagrams.

The paper by Edward Wegmann, M. Am. Soc. C. E., entitled "The Design of the New Croton Dam," was discussed by Messrs. Wagoner, Marx, Dillman, Duryea, and Hindes.

The paper by A. L. Adams, M. Am. Soc. C. E., entitled "Additional Information on the Durability of Wooden Stave Pipe," was discussed by Messrs. Duryea, Holmes, Marx, Galloway, Adams, Hindes, Hyde, A. M. Bienenfeld, and B. Bienenfeld. Mr. Duryea exhibited a section of wooden stave pipe taken from a sewer outlet in Palo Alto, which had been in use about eight years. It had been buried in a salt marsh. The wood was sound, but the iron or steel bands were badly corroded.

The paper by W. F. Dennis, M. Am. Soc. C. E., entitled "Uniformity of Requirement and Clearness of Specification in Agreements for the Graduation of Railroads," was discussed by Mr. Dillman.

Adjourned.

ACCESSIONS TO THE LIBRARY.

From February 12th, to March 9th, 1907.

DONATIONS.*

THE SIX-CHORD SPIRAL.

By J. R. Stephens. Cloth, 8 x 5 in., illus., 7 + 68 pp. New York, The Engineering News Publishing Co., 1907. $1.25 net.

The author states that the Six-Chord Spiral as outlined in this book has several valuable features: It is flexible and always fits; no special tables are required for general use; it is adapted to the curve; with it odd curves are fitted as readily as even ones; intermediate transit points may be set at any plus; the method is easily learned, memorized and applied; and the spiral is interchangeable with the cubic parabola. The first part of the book deals with the location and construction of spirals. The importance of a proper length of spiral is dwelt upon, and methods are given to insure consistency with varying conditions of speed and curve. Comparisons are also made between the spirals commonly used. The subject of spiraling old track is taken up in the second part, with the necessary methods, curves, etc. There is no index.

CONCRETE FACTORIES.

An Illustrated Review of the Principles of Construction of Reinforced Concrete Buildings, Including Reports of the Sub-Committee on Tests, the U. S. Geological Survey and the French Rules on Reinforced Concrete. Comp. by Robert W. Lesley, Assoc. Am. Soc. C. E. Boards, 10 x 7 in., illus., 152 pp. New York, Bruce & Banning. $1.00. (Donated by the Compiler.)

The Contents are: Introduction; Report of the Sub-Committee on Tests; United States Advisory Board on Fuels and Structural Materials; French Rules on Reinforced Concrete; Reinforced Concrete Construction; Concrete in Factory Construction; A Surface Finish for Concrete; Value of Concrete as a Structural Material; Miscellaneous Illustrations.

SANITARY ENGINEERING.

With Respect to Water-Supply and Sewage Disposal. By Leveson Francis Vernon-Harcourt. Cloth, 9 x 6 in., illus., 21 + 419 pp. London, Longmans, Green and Co., 1907. $4.50.

This volume forms one of the Longmans' Civil Engineering Series. It is stated that as the subjects, water supply and sewage disposal, form the basis of sanitary science, it was thought they might be treated advantageously in one volume. The first part of the book is devoted to water supply, its history, its various sources, the construction of dams and reservoirs, its purification and distribution. The second part takes up the subject of sewage disposal. The language used is as non-technical as possible, the author hoping in this way to make the book of interest to the general public as well as to the engineering profession. The Contents are: Part I, Water Supply-Introduction; Ancient Waterworks; and Available Rainfall; Sources of Water-Supply; Wells; Deep Wells; Lakes and Storage Reservoirs; Earthen and Rubble Reservoir-Dams; Masonry Dams; Typical Masonry Dams; Intakes. and Conveyance and Storage of Supply; Purification of Water-Supplies; Distribution of Water-Supply. Part II, Sewage Disposal: House Drainage, and Disposal of Refuse; Sewerage; Outfalls; and Clarification of Sewage; Utilization and Purification of Sewage on Land; Chemical, Electrolytic and Bacterial Purification of Sewage. There is an index of twenty-three pages.

LEAD SMELTING AND REFINING

With Some Notes on Lead Mining. Edited by Walter Renton Ingalls. Cloth, 9 x 6 in., illus., 7+ 327 pp. New York, The Engineering and Mining Journal, 1906. $3.00.

This book, as stated by the editor, is a reprint of articles pertaining to the smelting and refining of lead, and to the mining of lead ore. The articles have appeared in the *Engineering and Mining Journal* during the last three years,

* Unless otherwise specified, books in this list have been donated by the publisher.

some being abstracts of papers presented before engineering societies, or published in other technical periodicals. Several have also been reprinted from the *Transactions* of the American Institute of Mining Engineers. The subject-matter relates to various subjects of importance in the practical metallurgy of lead, especially in connection with the desulphurization of galena by "lime roasting" processes. These processes have been developed so recently that, as stated in the preface, until now, treatises on the subject have appeared only in technical periodicals and transactions of engineering societies. The Contents are: Notes on Lead Mining; Roast-Reaction Smelting (Scotch Hearths and Reverberatory Furnaces); Sintering and Briquetting; Smelting in the Blast Furnace; Lime-Roasting of Galena; Other Methods of Smelting; Dust and Fume Recovery (Flues, Chambers, and Bag-Houses); Blowers and Blowing Engines; Lead Refining; Smelting Works and Refineries. There is an index of four pages.

Gifts have also been received from the following:

Am. Ceramic Soc. 1 vol.
Am. Soc. of Mech. Engrs. 1 bound vol., 1 vol.
Am. Water-Works Assoc. 1 bound vol.
Andrews, Horace. 1 pam.
Assoc. of Ry. Supt. of Bridges and Bldgs. 1 vol.
Canada-Geol. Survey. 5 pam.
Canadian Min. Inst. 1 vol.
Chicago, Peoria & St. Louis Ry. Co. of Illinois. 1 pam.
Citizens East Side Improvement Assoc. of the City of New York. 2 pam.
Columbia Univ. 1 vol.
Delaware, Lackawanna & Western R. R. Co. 1 pam.
Great Britain-Patent Office. 9 vol., 5 pam.
Harrisburg, Pa.-Board of Commrs. of the Water and Lighting Dept. 1 pam.
Illinois Univ.-Eng. Exper. Station. 1 bound vol.
Illinois Univ.-State Water Survey 1 pam.
Incorporated Assoc. of Municipal and County Engrs. 1 bound vol.
India-Ry. Board. 1 pam.
Institution of Engrs. and Shipbuilders in Scotland. 1 bound vol.
Institution of Gas Engrs. 1 bound vol.
Japan-Imperial Earthquake Investigation Comm. 3 pam.
Kgl. Technische Hochschule zu Berlin. 1 pam.
Koninklijk Instituut van Ingenieurs. 1 pam.
Lafayette Coll. 1 pam.
Lawrence, Mass.-City Engr. 2 pam.
Leffler, B. R. 1 bound vol.
Lentilhon, Eugene. 1 pam.
Merchants' Assoc. of New York. 1 pam.
Midland Ry. Co. 1 pam.
Milliken Bros. 1 pam.
National Assoc. of Cotton Mfrs. 1 bound vol.
New York-State Library. 2 bound vol.
New York-State Water Supply Comm. 1 bound vol.
New York City. North Side Board of Trade. 1 pam.
New York City Record. 1 bound vol.
North, E. P. 1 pam.
Oberlin Coll. Library. 1 pam.
Paterson, N. J.-Joint Comm. on Sewage Disposal. 1 bound vol.
Pennsylvania-Water Supply Comm. 1 pam.
Pennsylvania R. R. Co. 1 pam.
Royal Philosophical Soc. of Glasgow. 1 vol.
St. Louis, Mo.-Water Commr. 6 bound vol., 6 pam.
Smithsonian Institution. 2 bound vol., 1 pam.
Soc. d'Encouragement pour l'Industrie Nationale. 1 vol.
Tonkin Thomas, Juan. 1 vol.
U. S. Bureau of Mfrs. 1 pam.
U. S. Geol. Survey. 3 pam.
U. S. Lake Survey Office. 5 maps.
U. S. Light-House Board. 1 bound vol.
U. S. Office of Exper. Stations. 1 pam.
U. S. Office of Public Roads. 17 pam.
U. S. Ordnance Dept. 1 vol.
Vernon-Harcourt, L. F. 1 pam.
Webster, A. L., 16 vol.
Wellington N. Z.-Harbour Board. 1 pam.
Western Australia-Commr. of Rys. 1 vol.
Whinery, S. 1 pam.
White, *Sir* W. H. 1 pam.

BY PURCHASE.

International Railway Congress Association. Seventh Session, Washington, May, 1905. Proceedings (English Edition); Vol I. Brussels, P. Weissenbruch, 1906.

Locomotive Performance. The Result of a Series of Researches Conducted by the Engineering Laboratory of Purdue University. By William F. M. Goss. New York, John Wiley & Sons, 1907.

United States Official Postal Guide. January, 1907. Albany, J. B. Lyon Company, Printers.

Testimony in the Patent Litigation Between the Cameron Septic Tank Co. and the Village of Saratoga Springs. Pleadings and Proofs. Saratoga Springs, John J. Healey, Jr., 1905.

Neue Theorie und Berechnung der Kreiselräder. Wasser- und Dampfturbinen, Schleuderpumpen und Gebläse Turbokompressoren, Schraubengebläse und Schiffspropeller. Von Dr. Hans Lorenz. München und Berlin, R. Oldenbourg, 1906.

SUMMARY OF ACCESSIONS.

From February 12th to March 11th, 1907.

Donations (including 13 duplicates)	134
By purchase	5
Total	139

MEMBERSHIP.

ADDITIONS.

MEMBERS.		Date of Membership.
ASHMEAD, PERCY HERBERT. Care, J. G. White & Co., 43 Exchange Pl., New York City		Mar. 6, 1907
BIENENFELD, ABEL MORRIS. Cons. Engr., 1119 Kohl Bldg., San Francisco, Cal		Feb. 6, 1907
CORY, HARRY THOMAS. Gen. Mgr. and Chf. Engr., The California Development Co., Calexico, Cal	Jun.	June 20, 1893
	Assoc. M.	Mar. 7, 1900
	M.	Feb. 5, 1907
GARRETT, ROBERT PEEL. Secy., Missouri Bridge & Iron Co., St. Louis, Mo.	Jun.	Jan. 4, 1898
	Assoc. M.	Oct. 2, 1901
	M.	Mar. 5, 1907
HAND, FRANKLIN CLARK. Chf. Engr., Oklahoma Central Ry. Co., Purcell, Ind. T		Feb. 6, 1907
HARDING, JAMES JUDSON. Engr. of Masonry Constr., C., M. & St. P. Ry. Co., 1359 Railway Exchange, Chicago, Ill		Feb. 6, 1907
HILL, HENRY FRANCIS. Chf. Engr., Somerset Ry., 12 Lincoln St., Augusta, Me		Mar. 6, 1907
HOLMES, GLENN DICKINSON. Engr. of Water Supply, Barge Canal, Weigh Lock, Syracuse, N. Y.	Assoc. M.	June 5, 1901
	M.	Mar. 5, 1907
LEAVENWORTH, GEORGE STEVENS. Chf. Engr., Powers & Mansfield Co., 297 River St., Troy, N. Y.	Assoc. M.	June 3, 1903
	M.	Mar. 5, 1907
MULHOLLAND, WILLIAM. Supt., Los Angeles Water Dept., 440 S. Hill St., Los Angeles, Cal		Feb. 6, 1907
PHILIPS, JAMES HARRY. Engr. and Asst. Supt., Atlantic, Gulf & Pacific Co., Comstock, N. Y		Feb. 6, 1907
ROY, ROBERT MAITLAND. Asst. to Pres. and Mgr., The Hamilton Bridge Works Co., Ltd., Hamilton, Ont., Canada	Assoc. M.	Oct. 3, 1900
	M.	Mar. 5, 1907
SHEDD, FRANK EDSON. Vice-Pres., Lockwood, Greene & Co., Archts. and Engrs., 93 Federal St., Boston, Mass		Feb. 6, 1907
SMITH, FRANCIS BETTS. 720 Napa St., Vallejo, Cal		Jan. 2, 1907
WENZELL, ANDREW JACKSON. Chf. Engr., Pearl River Val. R. R. Co., 864 Fourth Ave., Detroit, Mich		Oct. 3, 1906
WEYMOUTH, FRANK ELWIN. Project Engr., Lower Yellowstone Project, U. S. Reclamation Service, Glendive, Mont.	Assoc. M.	Sept. 4, 1901
	M.	Feb. 5, 1907
WOLFE, CHRISTIAN JOHN. 525 Fifty-eighth St., Brooklyn, N. Y		Mar. 6, 1907

ASSOCIATE MEMBERS.		Date of Membership.
BALLOU, HENRY WELCOME. Room 735, Banigan Bldg., Providence, R. I.		Nov. 7, 1906
BASSELL, GUY MANNERING. Res. Engr., S. & W. Ry., Erwin, Unicoi Co., Tenn.		Feb. 6, 1907
BERRY, CLAUDE. Contr. Engr., Minneapolis Steel & Machinery Co., 633 Monadnock Bldg., San Francisco, Cal.		Feb. 6, 1907
DANIELS, THOMAS REMINGTON HOLDEN. Care, Chf. Engr.'s Office, United Railroads of San Francisco, San Francisco, Cal.		Feb. 6, 1907
DUNNELLS, CLIFFORD GEORGE. Designing Engr., Am. Bridge Co., 1456 Frick Bldg. Annex, Pittsburg, Pa.	Jun. Assoc. M.	Feb. 4, 1902 Jan. 2, 1907
HANCOCK, LEWIS WERNETTE. 1318 Brook St., Louisville, Ky.		Jan. 2, 1907
HEBARD, ROY WILLIAM. Asst. Engr., Isthmian Canal Comm., San Pablo, Canal Zone, Panama.		Feb. 6, 1907
HULSE, SHIRLEY CLARK. Tucker & Vinton, 156 Fifth Ave., New York City.	Jun. Assoc. M.	Oct. 7, 1902 Feb. 6, 1907
HUNT, LEIGH ANSON. Pres. and Gen. Mgr., Hunt Eng. Co., Iola, Kans.		Feb. 6, 1907
HUNTER, JOHN. The Brown-Hunter Co., Cons. and Contr. Engrs., Youngstown, Ohio.		Feb. 6, 1907
JOHNSTON, JULIUS GERARDUS. 728 Fisk St., Alexandria, La.		Feb. 6, 1907
LOEWENSTEIN, JACOB. With Empire Bridge Co., 42 Broadway, New York City.		Feb. 6, 1907
LOVE, ANDREW CAVITT. Res. Engr., Baton Rouge Branch, Morgan's Louisiana & Texas R. R. & Steamship Co., Port Allen, La.		Feb. 6, 1907
MORRIS, CLYDE TUCKER. Associate Prof. of Civ. Eng., Ohio State Univ., Columbus, Ohio.		Mar. 6, 1907
OTT, SAMUEL JACOB. Asst. Engr., Designing and Estimating Office, Am. Bridge Co., 103 W. Passaic Ave., Rutherford, N. J.		Feb. 6, 1907
REIMER, ARTHUR ADAMS. Engr. and Supt., East Orange Water Dept., 45 South Maple St., East Orange, N. J.		Mar. 6, 1907
SACKETT, ROBERT LEMUEL. Richmond, Ind.		Feb. 6, 1907
SIMPSON, PAUL DYER. Asst. Engr., U. S. Reclamation Service, Crawford, Nebr.		Feb. 6, 1907
SINNICKSON, GEORGE ROSENGARTEN. 230 West Rittenhouse Sq., Philadelphia, Pa.	Jun. Assoc. M.	Sept. 5, 1899 Feb. 6, 1907

ASSOCIATE MEMBERS (*Continued*).

	Date of Membership.
WHITNEY, THOMAS BRYAN, Jr. Asst. Engr., Hudson Companies, 111 Broadway, New York City..... { Jun. / Assoc. M.	Sept. 6, 1898 / Feb. 6, 1907
WISE, JAMES HUGH. Asst. Hydr. and Civ. Engr., California Gas & Elec. Corporation, 925 Franklin St., San Francisco, Cal.....	Feb. 6, 1907
WOOD, DETHIC HEWITT. Chf. Engr., Converse Bridge Co., 101 Chamberlain Ave., Chattanooga, Tenn..	Feb. 6, 1907

ASSOCIATES.

CONSTANCE, EDWARD CARTWRIGHT. Surv., U. S. Engr. Office, Custom House, St. Louis, Mo..... { Jun. / Assoc.	Dec. 6, 1904 / Feb. 6, 1907
COOPER, WILLIAM HILL. Supt. and Gen. Mgr., The Chuctanunda Gas Light Co., Amsterdam, N. Y..	Feb. 6, 1907
DE WYBALL, CYRIL. Chf. Insp., Interborough Rap. Trans. Co., Subway Div., New York City; Address, Ridgefield Park, N. J.....	Feb. 6, 1907

JUNIORS.

ANDERBERG, EDWARD. 238 Tremont St., North Tonawanda, N. Y.....	Mar. 5, 1907
BANKS, CHARLES WILBUR. P. O. Box 154, Mt. Kisco, N. Y.....	Feb. 5, 1907
BARKER, LUDLOW OSMOND, Jr. Care, Chf. Engr.'s Office, S. & W. R. R., Johnson City, Tenn.....	Jan. 3, 1907
BIXBY, WILLIAM FLINT. Eng. Dept., City Hall, Los Angeles, Cal.....	Feb. 5, 1907
CHADWICK, CHESTER ROBERT. 317 West 56th St., New York City.....	Feb. 5, 1907
COYNE, HARRY LOUIS. 509 West 146th St., New York City.....	Feb. 5, 1907
FARLEY, MARCUS MARTIN. Asst. Engr., Board of Water Supply of New York, 299 Broadway, New York City.....	Sept. 4, 1906
FINCH, STANLEY PHISTER. 2306 San Antonio St., Austin, Tex.....	Oct. 30, 1906
GILDERSLEEVE, GEORGE SNYDER. 533 Cass Ave., Detroit, Mich.....	Feb. 5, 1907
GREELEY, SAMUEL ARNOLD. Care, Hering & Fuller, 170 Broadway, New York City.....	Feb. 5, 1907
HINMAN, LEROY RACE. Box 352, Boise, Idaho.....	Feb. 5, 1907
JOHNSON, GRANVILLE. 79 Bellevue St., Boston, Mass...	Mar. 5, 1907
LITTLEFIELD, EMMETT. 115 West 97th St., New York City.....	Feb. 5, 1907

JUNIORS (*Continued*).

	Date of Membership.
LYNCH, EDWIN LEWIS. 23 Emerson St., Portland, Me...	Feb. 5, 1907
MOSER, ALBERT LEO BRECHT. 695 Wilson Ave., Chicago, Ill.....	Jan. 3, 1907
PAIGE, JASON. Asst. Engr., Constr., Joseph T. Ryerson & Son, 18 Milwaukee Ave., Chicago, Ill.....	Feb. 5, 1907
RIEGEL, ROSS MILTON. 804 E. Seneca St., Ithaca, N. Y..	Mar. 5, 1907
SMITH, FRANCIS MARSHALL. Asst. Engr., N. P. Ry., St. Paul, Minn.....	Jan. 3, 1907
SUTTLE, CLIFFORD BRADLEY. Care, John A. Cole, 310 Ashland Blk., Chicago, Ill.....	Oct. 30, 1906
THOMSON, WARREN BROWN. 295 Church St., Poughkeepsie, N. Y.....	Feb. 5, 1907

CHANGES OF ADDRESS.

MEMBERS.

ADAMS, ARTHUR LINCOLN. Cons. Hydr. Engr., 1014 Broadway, Oakland, Cal.

BARCROFT, FREDERICK THOMAS. Archt. and Engr., 804 Penobscot Bldg., Detroit, Mich.

BECKWITH, FRANK. Care, N. P. Ry., Drummond, Mont.

BISHOP, HUBERT KEENEY. 98 So. Swan St., Albany, N. Y.

COBY, HARRY THOMAS. Gen. Mgr. and Chf. Engr., The California Development Co., Calexico, Cal.

DAUCHY, WALTER EDWARD. Div. Engr., C., M. & St. P. Ry. of Wash., Missoula, Mont.

DIDIER, PAUL. Dist. Engr., B. & O. R. R. Co., Allegheny City, Pa.

EDES, WILLIAM CUSHING. Chf. Engr., Northwestern Pacific R. R. Co., James Flood Bldg., San Francisco, Cal.

EVANS, GEORGE EDWIN. Civ. and Hydr. Engr., 328 Wilder St., Lowell, Mass.

FILLEY, HIEL HAMILTON. Care, Curtis & Hine, Giddings Bldg., Colorado Springs, Colo.

FOWLER, THOMAS WALKER. Civ., Mech. and Elec. Engr., 421 Collins St., Melbourne, Victoria, Australia.

GERIG, WILLIAM. Div. Engr., Isthmian Canal Comm., Cristobal, Canal Zone, Panama.

GOODALE, LOOMIS FARRINGTON. Superv. Railway Expert for Philippine Islands Comm., Manila, Philippine Islands.

HARROD, BENJAMIN MORGAN. Cons. Engr., 1637 Foucher St., New Orleans, La.

HERRON, JOHN. 105 Emerson St., Palo Alto, Cal.

HILL, LOUIS CLARENCE. Superv. Engr., U. S. Reclamation Service, Phœnix, Ariz.

HILL, WALTER HOVEY. Cons. Engr., P. O. Box 342, Cobalt, Ont., Canada.

MEMBERS (*Continued*).

HINCKLEY, HOWARD VERNON. Cons. Civ. Engr.; Pres., Sulphur Light & Power Co., Sulphur, Ind. T.

HOWARD, CHARLES POPE. Chf. Engr., Va. Air Line Ry., Charlottesville, Va.

HUGGINS, WILLIAM. Care, Companhia Bocas de Santos, Secção de Construcção, Santos, Brazil.

HUMPHREY, HENRY CYPRIAN. Dist. Engr., 8th Dist., Albay; Address, Legaspi, Albay Province, Philippine Islands.

KEITH, GEORGE THOMAS. Res. Engr., Water Supply, Barge Canal, Rome, N. Y.

LOCKWOOD, WILLARD DATUS. Supt. of Constr., The Scofield Co., Amsterdam, N. Y.

MATCHAM, CHARLES ARTHUR. 1727 Hamilton St., Allentown, Pa.

MICHELL, THEOPHILUS. Chf. Engr., State Railways, India (*Retired*), Trewirgie, Wellington Rd., Bournemouth, England.

MOLITOR, FREDERIC ALBERT. Care, University Club, Philadelphia, Pa.

MÜNSTER, ANDREW WENDELBO. Cons. Engr., 61 Maynard Bldg., Seattle, Wash.

OAKLEY, FRANK THOMPSON. Asst. Engr., Peoples Water Co., 1014 Broadway, Oakland, Cal.

PIERCE-HOPE, JOHN. Dirección General de Obras Públicas, La Paz, Bolivia.

RENSHAW, ALFRED HOWARD. Noroton, Conn.

RIPLEY, HENRY CLAY. Civ. and Cons. Engr., Chillicothe, Ill.

SMITH, STEWART KEDZIE. Dist. Mgr., Dering Coal Co., Terre Haute, Ind.

STANFORD, HOMER REED. Civ. Engr., U. S. N., Bureau of Yards and Docks, Navy Dept., Washington, D. C.

STEPHENS, CLINTON F. P. O. Box 448, Manila, Philippine Islands.

WATKINS, RICHARD. Roma, Livingstone Rd., Dulwich Hill, near Sydney, New South Wales, Australia.

WILSON, CHARLES BEATTY. Roadmaster, N., C. & St. L. Ry., 810 Woodland St., Nashville, Tenn.

ZOOK, MORRIS ALEXANDER. Cons. and Civ. Engr., Plainfield, N. J.

ASSOCIATE MEMBERS.

ADAMS, EDWARD MAGUIRE. Capt., Corps of Engrs., U. S. A., U. S. Engr. Office, Pittsburg, Pa.

ARMSTRONG, ALEXANDER FLOYD. Engr., Maintenance and Operation, Truckee-Carson Irrig. System, U. S. Reclamation Service, Fallon, Nev.

BROWN, STEPHEN PEARSON. 55 East 76th St., New York City.

BRUSH, WILLIAM WHITLOCK. Care, Board of Water Supply, 299 Broadway, New York City.

COLE, BURT. Merryville, Calcasieu Parish, La.

DEGRAFF, HARRY WESTBROOK. Barge Canal Res. Engr., Barge Canal Office, Fulton, N. Y.

ASSOCIATE MEMBERS (*Continued*).

DREW, CHARLES DAVIS. Steam Line Engr., With J. G. White & Co., Ltd., 1523 Tucuman, Buenos Aires, Argentine Republic.

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DEATHS.

BACON, JOHN WATSON. Elected Member, July 12th, 1877; died February 27th, 1907.

DAVIS, CHARLES. Elected Member, September 15th, 1869; died February 21st, 1907.

EVANS, MYRON EDWARD. Elected Junior, January 3d, 1895; Associate Member, February 7th, 1900; died February 16th, 1907.

MACLENNAN, JOHN DONALD. Elected Member, October 4th, 1899; died February 26th, 1907.

SEYMOUR, HORATIO. Elected Associate, January 8th, 1873; Member, April 7th, 1880; died February 21st, 1907.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(February 11th to March 9th, 1907.)

NOTE.—*This list is published for the purpose of placing before the members of the Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles, references are given by the number prefixed to each journal in this list.

(1) *Journal*, Assoc. Eng. Soc., 31 Milk St., Boston, Mass., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England. 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générales des Chemins de Fer et des Tramways*, Paris, France.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.

(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 803 Fulton Bldg., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne, England.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Industrial World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(70) *Engineering Review*, New York City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.
(72) *Electric Railway Review*, Chicago, Ill., 10c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, Ill., 10c.
(77) *Journal*, Inst. Elec. Engrs., London, England.
(78) *Beton und Eisen*, Vienna, Austria.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie-Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Dinglers Polytechnisches Journal*, Berlin, Germany.
(83) *Progressive Age*, New York City, 15c.
(84) *Le Ciment*, Paris, France.
(85) *Proceedings*, Am. Ry. Eng. and M. of W. Assoc., Chicago, Ill.
(86) *Engineering World*, Chicago, Ill.
(87) *Railway Maintenance and Structures*, New York City, 10c.

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Handling Eyebars at the Quebec Bridge.* (14) Feb. 9.
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The Connecticut Avenue Bridge, Washington, D. C.* (14) Feb. 16.
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The Elizabeth Suspension Bridge at Budapest.* J. B. Van Brussel. (86) Feb. 22.
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The Traveler for the Erection of the Quebec Bridge.* (14) Feb. 23.
The Bronx River Bridge at East 233d St., New York. (14) Feb. 23.
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Erection of the Cantilever Spans of the Blackwell's Island Bridge.* (14) Mar. 2.
Erection of the Lehighton Bridge of the Central Railroad of New Jersey.* (14) Mar. 2.
Steel Sheet Piling for Bridge Pier Cofferdams.* (14) Mar. 2.
Building the Washington Street Bridge in Dayton, Ohio.* (14) Mar. 2.
The Reinforced Concrete Viaduct of the Richmond & Chesapeake Bay Railway at Richmond.* (14) Mar. 2.
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Ponts en Béton à Trois Rotules sur l'Iller à Lautrach et à Kempten (Bavière). (33) Feb. 16.
Die Eisenbahn- und Strassenbrücke über den Oberhafen in Hamburg.* Merling. (49) Vol. 1 and 2, 1907.

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Electrical.

Alternating Current Electrolysis.* J. L. R. Hayden. (42) Feb.
Electrolytic Corrosion of Iron and Steel in Concrete.* A. A. Knudson. (42) Feb.
Some Theoretical Notes on the Reduction of Earth Currents from Electric Railway Systems by Means of Negative Feeders.* George I. Rhodes. (42) Feb.
High-Tension Outlets.* Alvin Meyers. (42) Feb.
Underground Transmission and Distribution of Electrical Energy.* Charles E. Phelps. (42) Feb.
Motor-Generators *vs.* Synchronous Converters; with Special Reference to Operation on Long-Distance Transmission Lines. P. M. Lincoln. (42) Feb.
Introduction to Discussion on the Practicability of Large Generators Wound for 20 000 Volts.* B. A. Behrend. (42) Feb.
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The Necaxa Power Plant, Mexico.* (26) Feb. 15.
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The Continuous Production of High-Frequency Oscillations.* R. A. Fessenden. (73) Serial beginning Feb. 15.
Electric Generating Station of the Paxtang Electric Company of Harrisburg, Pa.* (27) Feb. 16.
Calculation of Dynamo Sparking Characteristics.* Carlton L. Kennedy. (27) Feb. 16.
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Self-Regulating Alternator with Auxiliary Field.* A. Heyland. (27) Feb. 23.
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Advantages and Applications of the Electric Drive.* F. B. Crocker and M. Arendt. (19) Serial beginning Mar. 2.
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Fortschritte auf dem Gebiete der Funkentelegraphie.* Otto Nairz. (82) Feb. 2.
Grossstädtische Kraftwerke für Privatbetriebe.* E. Josse. (48) Serial beginning Feb. 16.

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The New Naval Docks at Devonport.* (11) Serial beginning Feb. 15.
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New Types of Gas Engines for Marine Work.* A. B. Willets. (46) Feb. 23.
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Bearings.* (55) Vol. 27.
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The Application of Large Gas-Engines in the German Iron and Steel Industries.* K. Reinhardt. (71) Vol. 71.
Note on Large Gas-Engines Built in Great Britain and upon Gas-Cleaning.* Tom Westgarth. (71) Vol. 71.
The Development of the Roe Puddling Process.* James P. Roe. (71) Vol. 71.
Improvements in Rolling Iron and Steel.* James E. York. (71) Vol. 71.
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Manufacture of Tin-Plates.* R. Beaumont Thomas. (75) July.
Large Testing-Machines in South Wales, 1829-1906.* J. Hartley Wicksteed. (75) July.
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Illinois Coal Tests. Henry B. Dirks. (Paper read before the Ill. Soc. of Engrs. and Surv.) (14) Feb. 23.
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AMERICAN SOCIETY OF CIVIL ENGINEERS.

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PAPERS AND DISCUSSIONS.

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THE LAWS OF PROPORTIONING CONCRETE.

By William B. Fuller and Sanford E. Thompson,
Members, Am. Soc. C. E.

To Be Presented April 17th, 1907.

Experiments made by one of the authors at Little Falls, N. J., in 1901, upon the density and transverse strength of concrete beams mixed in various proportions, by weight, ranging in proportions from 1:0 to 1:6:10, indicated that the strength of concrete varies with the percentage of cement contained in a unit volume of the set concrete, and also with the density of the specimen. With the same percentage of cement in a given volume of concrete, the densest mixture, irrespective of the relative proportions of the sand and stone, was in general the strongest.

The Little Falls tests further indicated that for the materials used there was a certain mixture of sizes of grains of the aggregate which, with a given percentage, by weight, of cement, to the total aggregate, gave the highest breaking strength. In practice, also, it was found that the concrete made with this mixture worked most smoothly in placing. The mixture of sizes of particles of aggregate which appeared to give the best results gave for its mechanical analysis a curve approaching a parabola, with its begin-

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

ning at zero of co-ordinates, and passing through the intersection of the curve of the coarsest stone with the 100% line, that is, passing through the upper end of the coarsest stone curve.

Graded stone of the same maximum diameter and character was used in all the Little Falls experiments, and the laws mentioned were discovered by a comparison of the final results of the tests rather than by logical investigation.

These results were brought to the attention of the Aqueduct Commission of the City of New York in 1903 by J. Waldo Smith, M. Am. Soc. C. E., then Chief Engineer for the Commission, and at his suggestion the Commission authorized a further study of these and related matters, the results of which study are here presented.

The experiments to be mentioned were carried on at Jerome Park Reservoir, in the Bronx District, where a large amount of concrete construction was being done by contract under the supervision of the Commission, and cement, sand and stone were readily available. A large, light and warm room was provided as a laboratory, and the necessary apparatus was purchased. Sufficient labor and other assistance was always obtainable from the Contractors or from the Engineering and Inspection staff on the Reservoir Construction.

As has been stated, previous tests indicated that the greatest strength from any given percentage of cement was obtained when the concrete was of the greatest possible density, that is, having the least percentage of voids, and further, that the greatest density was obtained when all the materials were proportioned so as to give a regular mechanical analysis curve approaching a parabola. It also appeared probable that concrete of the greatest density would be the least permeable to water.

With the foregoing laws established, it would be possible to compare the values of different aggregates and various proportions of the same aggregates by volumetric tests, the best mixture in general giving the smallest volume of concrete.

The tests were accordingly arranged with the view of fixing the limitations of this theory, to ascertain the effect of different aggregates upon the density, strength and permeability of concrete, and particularly to determine the exact sizes of aggregate which,

mixed together with a given proportion of cement, would form the best concrete. The density and strength of concrete made up of an aggregate of ideal mechanical analysis and of different maximum size was compared with the density and strength of concrete made of average sand and stone or gravel in ordinary nominal mixtures.

The relative permeability of concrete with different aggregates and different proportions of cement was also studied.

It also became necessary to study many related subjects, such as the physical characteristics of different cements, broken stone, broken-stone screenings, gravel and sand, especially with reference to specific gravity, weight, voids, density, etc. Each material was tested by itself and when mixed in various proportions with others.

The experiments were begun with a series of tests of the density of different mixtures of aggregates and cement, to study the laws of proportioning for maximum density with different materials, and these density experiments were followed by the manufacture of concrete beams for comparing the laws of strength with the laws of density, and determining the relation between these two causes. As the compressive strength of concrete is a truer measure of its quality than the transverse strength—which in the case of concrete is really one form of tension test—two pieces of each beam after being broken in the beam machine were capped with neat cement so as to form prisms, and these were tested for compressive strength; a number of them were also tested for the compressive modulus of elasticity. A selected number of pieces of the broken beams were also tested for permeability.

Other secondary experiments, upon the density of mortars and the quantity of water required for different sizes of sand, were begun, and although not extended far enough to reach definite conclusions, the results are of interest as indicating the possibilities of another important line of investigation. It was intended to use these results further as preliminary to a series of permeability tests of mortars composed of cement and sand having grains of different size, and containing admixtures of puzzolan cement and of hydrated lime.

Conclusions.

The following conclusions have been drawn from the tests. Many of them introduce laws which the writers believe have not

hitherto been recognized, and are opposed in certain cases to current ideas. Although based upon experiments with but two aggregates, these were so characteristic as to make the various comparative results of nearly general application.

Unless otherwise designated, the percentage of cement and the relative grading of the aggregates remain the same.

1.—Stone of the largest size makes the strongest concrete under both compression and transverse loading, *i. e.*, a graded aggregate in which the maximum size of the stone is 2½ in. in diameter gives stronger concrete than a graded aggregate with 1-in. maximum size, and the 1-in. stone gives a stronger concrete than ½-in. stone. A concrete in which the graded aggregate runs to 1 in. in maximum size will require for equal strength about one-sixth more cement, and with an aggregate running to ½ in. maximum size about one-third more cement than concrete with an aggregate in which the maximum size is 2½ in.

2.—The largest stone makes the densest concrete. Concrete made with graded stone having a maximum diameter of 2½ in. is noticeably denser than that with 1-in. stone, and this is denser than that with ½-in. stone.

3.—Round material like gravel, under similar conditions, gives a denser concrete than broken stone.

4.—Sand produces a denser concrete than screenings of similar sized grains.

5.—A concrete with an angular coarse aggregate, such as broken stone, is stronger than one with a rounded coarse aggregate, like gravel, and the same sand and cement—although the rounded aggregate produces greater density—thus indicating a stronger adhesion of cement to broken stone than to gravel. However, if the sand is also angular, like screenings, but with its grains of the same sizes as the sand, the concrete with rounded coarse and fine aggregate is the stronger, probably because of its greater density.

6.—Aggregates in which particles have been specially graded in sizes so as to give, when water and cement are added, an artificial mixture of greatest density, produce concrete of higher strength than mixtures of cement and natural materials in similar proportions. The average improvement in strength by artificial

grading under the conditions of the tests was about 14 per cent. Comparing the tests of strength of concrete having different percentages of cement, it is found that for similar strength the best artificially graded aggregate would require about 12% less cement than like mixtures of natural materials.

7.—The strength and density of concrete is affected but slightly, if at all, by decreasing the quantity of the medium size stone of the aggregate and increasing the quantity of the coarsest stone. An excess of stone of medium size, on the other hand, appreciably decreases the density and strength of the concrete.

8.—The strength and density of concrete is affected by the variation in the diameter of the particles of sand more than by variation in the diameters of the stone particles.

9.—An excess of fine or of medium sand decreases the density and also the strength of the concrete, as will also a deficiency of fine grains of sand in a lean concrete.

10.—The substitution of cement for fine sand does not affect the density of the mixture, but increases the strength, although in a slightly smaller ratio than the increase in the ratio of cement.

11.—It follows from the foregoing conclusions that the correct proportioning of concrete for strength consists in finding, with any percentage of cement, a concrete mixture of maximum density, and increasing or decreasing the cement by substituting it for the fine particles in the sand or *vice versa*.*

12.—In ordinary proportioning with a given sand and stone and a given percentage of cement, the densest and strongest mixture is attained when the volume of the mixture of sand, cement and water is so small as just to fill the voids in the stone. In other words, in practical construction, use as small a proportion of sand and as large a proportion of stone as is possible without producing visible voids in the concrete.

13.—The best mixture of cement and aggregate has a mechanical analysis curve† resembling a parabola, which is a combination of a curve approaching an ellipse for the sand portion and a tangent straight line for the stone portion. The ellipse runs to a diameter of one-tenth of the diameter of the maximum size of stone, and the stone from this point is uniformly graded.

* This very important law requires further tests for confirmation, outside of the limits of the present tests.

† For definition of mechanical analysis, see page 228.

14.—The ideal mechanical analysis curve, *i. e.*, the best curve, is slightly different for different materials. Cowe Bay sand and gravel, for example, pack closer than Jerome Park stone and screenings, and therefore require less of the size of grain which the writers designate as sand.

15.—The form of the best analysis curve for any given material is nearly the same for all sizes of stone, that is, the curve for ½-in., 1-in., and 2¼-in. maximum stone may be described by an equation with the maximum diameter as the only variable. In other words, suppose a diagram in which the left ordinate is zero, and the extreme right ordinate corresponds to 2¼-in. stone, with the best curve for this stone drawn upon it. If, now, on this diagram the vertical scale remains the same, but the horizontal scale is increased two and a quarter times, so that the diameter of 1-in. stone corresponds to the extreme right-hand ordinate, the best curve for the 1-in. stone will be very nearly the one already drawn for the 2¼-in. stone. The chief difference between the two is that the larger size of stone requires a slightly higher curve in the fine sand portion.

16.—It follows from this last conclusion that, from a scientific standpoint, the term "sand" is a relative one. With 2¼-in. stone, the best sand would range in size from 0 to 0.22 in. in diameter, while the best sand for ½-in. stone would range in size from 0 to 0.05 in. in diameter.

17.—The permeability or flow of water through concrete is less as the percentage of cement is increased, and in very much larger inverse ratio.

18.—The permeability is less as the maximum size of the stone is greater. Concrete with maximum size stone of 2¼-in. diameter is, in general, less permeable than that with 1-in. maximum diameter stone, and this is less permeable than that with ½-in. stone.

19.—Concrete of cement, sand and gravel is less permeable than concrete of cement, screenings and broken stone; that is, for equal permeability, a slightly smaller quantity of cement is required with rounded aggregates like gravel than with sharp aggregates like broken stone.

20.—Concrete of mixed broken stone, sand and cement is more permeable than concrete of gravel, sand and cement, and less per-

meable than similar concrete of broken stone, screenings and cement; that is, for water-tightness, less cement is required with rounded sand and gravel than with broken stone and screenings.

21.—The permeability decreases materially with age; increases nearly uniformly with the increase in pressure; and increases as the thickness of the concrete decreases, but in a much larger inverse ratio.

Mechanical Analysis.*

Mechanical analysis consists in separating the particles or grains of a sample of any material—such as broken stone, gravel, sand or cement—into the various sizes of which it is composed, so that the material may be represented by a curve, each ordinate of which is the percentage of the weight of the total sample which passes a sieve having holes of a diameter represented by the distance of this ordinate from the origin in the diagram.

The objects of mechanical analysis curves, as applied to concrete aggregates, are:

(1) To show graphically the sizes and relative sizes of the particles;

(2) To indicate what sized particles are needed to make the aggregate more nearly perfect and so enable the engineer to improve it by the addition or substitution of another material; and

(3) To afford means for determining the best proportions of different aggregates.

Materials.

Cement.—Portland cement from the regular shipments to the reservoir was used in all except a few comparative tests of different brands. This cement had been tested in the regular fashion for reservoir work, and, in addition, every bag which was used in the later experiments was subjected to the purity test. It was found that the cement used in the 1904 beams, which did not set up satisfactorily, failed to pass this test, while all the cement passing this test appeared to be satisfactory from a chemical standpoint.

* A description of the methods and apparatus for mechanical analysis, and for plotting the curves, may be found in the chapter by Mr. Fuller on proportioning concrete, in Taylor and Thompson's "Concrete, Plain and Reinforced."

Purity Test.—The purity test is as follows:

Provide a glass-stoppered bottle of muriatic acid, two shallow white bowls or two ½-in. by 6-in. test tubes, a glass rod, and a pair of rubber gloves. Put in a bowl or a tube as much cement as can be taken on a nickel 5-cent piece; moisten it with half a teaspoonful of water; cover with clear muriatic acid poured slowly upon the cement while stirring it with the glass rod. Pure Portland cement will effervesce slightly, give off some pungent gas, and gradually form a bright yellow jelly without any sediment. Powdered limestone or powdered cement-rock mixed with the pure cement will cause a violent effervescence, the acid boiling and giving off strong fumes until all the carbonate of lime has been consumed, when the bright yellow jelly will form. Powdered sand or quartz or silica mixed with cement will produce no other effect than to remain undissolved as a sediment at the bottom of the yellow jelly. Reject cement which has either of these adulterants.*

The results of tension tests on a sample of the cement used were as follows:

	Age, in days.		Age, in months.					
	1	7	1	2	3	4	5	6
Average tensile strength, in pounds per square inch.....	218	556	658	686	708	656	738	754

Aggregate.—Two classes of materials were used for the aggregate: broken stone and screenings from the crushers at the reservoir, and Cowe Bay gravel and sand dredged from the river.

The stone as it came from the crushers at Jerome Park was run through revolving screens to remove stones of greater diameter than 2 in., which were not permitted in the reservoir lining, and to separate the screenings, which were measured separately from the broken stone in proportioning the concrete.

The 1904 beams were made with material as it came from the crusher screens, this series being for approximate comparison of the strength of different proportions, while the density experiments

* Judson's "City Roads and Pavements," 1902.

were in progress. The density tests were a necessary preliminary to the more scientific mixtures made in 1905.

For the density tests and the specimens made in 1905, the stone and screenings were separated in the laboratory by twenty-one sieves ranging in size from 3-in. openings to No. 200 mesh—the latter corresponding to an opening of 0.0027 in. By using different mixtures of the sizes separated by these sieves, it was possible to obtain an infinite variety of proportions.

Character of Jerome Park Rock.—The rock at Jerome Park is technically a mica schist, containing about 35% mica, although the mica is in such a state that in concrete or mortar it does not form planes which affect the strength seriously. The variation in the quality of the rock in different parts of the reservoir gave some trouble in the laboratory, and led to less accuracy in the results of the density experiments, and in forming the proportions of the mixtures, than if the specific gravity had been uniform. The most noticeable difference in different ledges was in the predominance of quartz, some of the lots being lighter in color than the others. Since the specific gravity of the minerals in the native rock ranged from 2.6 to 3.2, the specific gravity of different lots of screenings varied appreciably, and the specific gravity of different diameters of the same rock also varied because some of the minerals of which the rock was composed crushed more readily than others, and therefore certain sizes contained predominating minerals which determined their specific gravities.

Character of Cowe Bay Materials.—The material from Cowe Bay is a water-worn rounded bank gravel and sand, thoroughly clean, and consisting almost entirely of quartz particles. Its specific gravity is quite uniform, being about 2.65.

Mechanical Analyses of Aggregates.—The average mechanical analyses of these materials are given in Table 1.

Screening Aggregate in Laboratory.—Large sieves, about 2 ft. square, were used for screening the aggregate into the twenty-one sizes. The sieves rested in a frame, one above another, seven to a frame, so that any one of them could be pulled out like a drawer without disturbing the others. The frames rested upon a pair of rockers consisting of 2-in. plank, sawed with angles instead of rounding, so that the motion of the sieves when rocked by hand

was a combined slide and jar. Spikes were driven into the rockers at the angles to make them more durable. A frame of sieves and a single sieve are shown in the background of the photograph, Fig. 2, Plate XII, and the details are shown in Fig. 1.

TABLE 1.

Diameter of opening in sieves, in inches.	Jerome Park Material.				Cowe Bay Sand and Stone.			
	2½-in. stone, percentage passing.	1-in. stone, percentage passing.	½-in. stone, percentage passing.	Screenings, percentage passing.	2½-in. stone, percentage passing.	1-in. stone, percentage passing.	½ in. stone, percentage passing.	Sand, percentage passing.
2.25	100.0	.....	.....	.....	100.0	.....	.....	100.0
1.50	78.4	.....	.....	.....	94.2	.....	.....	100.0
1.00	41.8	100.0	.....	.....	81.8	100.00	.....	100.0
0.75	29.9	71.5	.....	.....	67.3	82.27	.....	100.0
0.60	18.4	44.2	.....	100.0	44.8	54.77	.....	97.9
0.48	11.4	27.3	100.0	99.7	26.4	32.28	100.00	96.2
0.36	6.8	16.3	59.6	99.1	14.0	17.12	53.03	95.0
0.29	3.6	8.6	31.6	96.9	8.6	10.51	32.57	93.7
0.20	1.9	4.5	16.7	92.8	5.05	6.17	19.13	91.8
0.16	1.3	3.1	11.4	87.2	3.40	4.16	12.88	88.9
0.10	1.0	2.4	8.7	80.7	1.76	2.15	6.67	85.1
0.075	0.67	1.6	5.8	76.7	1.57	1.92	5.95	78.9
0.046	0.61	1.4	5.3	70.8	1.38	1.69	5.23	68.3
0.034	0.58	1.39	5.0	66.3	1.28	1.56	4.85	62.4
0.020	0.55	1.32	4.8	55.8	1.09	1.33	4.13	49.9
0.016	0.48	1.15	4.2	47.8	0.98	1.20	3.71	37.3
0.014	0.47	1.12	4.1	43.2	0.80	0.98	3.03	31.8
0.0071	0.32	0.76	2.8	21.0	0.47	0.57	1.78	7.1
0.0058	0.27	0.64	2.3	15.4	0.43	0.53	1.63	4.6
0.0036	0.19	0.45	1.6	6.7	0.26	0.32	0.98	2.3
0.0027	0.01	0.24	0.8	2.3	0.01	0.01	0.04	1.3

This apparatus worked fairly well, although difficulty was experienced in getting uniformity of screenings. It is suggested that for future work some form of pedometer be placed upon the frames to record the number of shakes, which number should be definitely fixed for each series of sizes. Each lot of unscreened material placed in the top sieve of each series should be measured so as not to overload the apparatus.

For testing small samples of aggregate, and for cement, the apparatus shown in Fig. 1, Plate XII, was used.

Diameters of Aggregates.—The diameters of particles in the tables and diagrams in this paper are designated by the size of the openings in the sieve, by the diameter of the largest particles passing through it, instead of by the commercial number of the sieve.

The diameters of particles, with the corresponding commercial sieve numbers used in this series of tests, are shown in Table 2.

TABLE 2.—SIZES OF SIEVES.

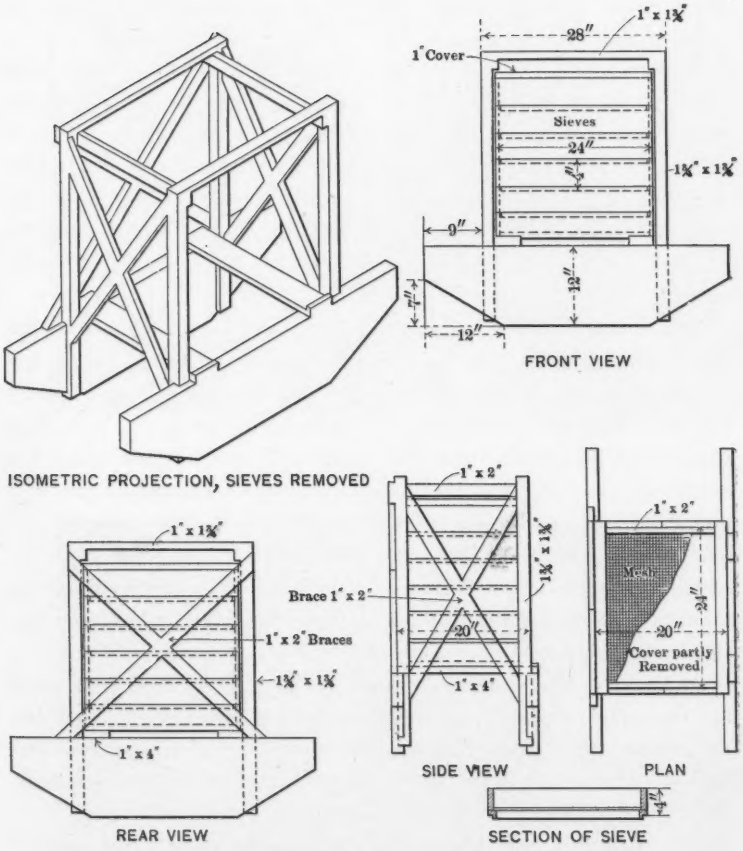
Normal sizes of sieves, in inches.	Diameters passing sieves, in inches.	Normal sizes of sieves, in inches.	Diameters passing sieves, in inches.	Commercial numbers of sieves, in inches.	Diameters passing sieves, in inches.	Commercial numbers of sieves, in inches.	Diameters passing sieves, in inches.
2.25	2.25	0.35	0.36	10	0.075	50	0.014
1.50	1.50	0.27	0.29	15	0.046	74	0.0071
1.00	1.00	0.20	0.20	20	0.034	100	0.0058
0.75	0.75	0.15	0.16	30	0.020	150	0.0036
0.60	0.60	0.10	0.10	40	0.016	200	0.0027
0.45	0.48						

The number of sieves adopted was so large that it required considerable time and labor in making each test. In future experiments, it may be possible to omit a few of the sizes, if tests of the materials indicate that this can be done without appreciable effect upon the result.

VOLUMETRIC TESTS.

Methods and Apparatus for Determining Density.—As a preliminary to the beam experiments, nearly 400 trial mixes of aggregates, composed of various sized particles, following a logical plan, and containing first 10% of cement to the total weight of the dry materials and then other percentages of cement, were made and mixed with water to the same medium wet consistency, and the resulting volumes thus obtained from exactly the same total weight of dry materials (corrected for specific gravity) were compared. The tests of density are termed volumetric tests in this paper. The general procedure (described below) in making them is that adopted by the French Commission, in 1894, and the volumes of material were calculated by methods used by M. R. Feret, of Boulogne-sur-Mer, France, in his determination of elementary and of absolute volumes. The apparatus used in these tests is shown in Fig. 1, Plate XII.

Weighing.—All materials were proportioned by dry weight. The stone and screenings were brought to the laboratory, and the screen-



DETAIL OF FRAME FOR SIEVES FOR SCREENING AGGREGATES IN LABORATORY.

FIG. 1.

ings dried in large pans on the stove. To hasten the drying, they were stirred continually, and, when dry fine dust freely arose from them, tests indicated that they contained no appreciable moisture. Tests showed that material stored in the laboratory for some time during the winter did not collect enough moisture to affect the weights used in the experiments.

For weighing the materials, a Fairbanks scale (No. 1 288) with a compound beam having seven scales, was used. The scales read to half pounds, and, with a wire rider made in the laboratory, it was possible to read to hundredths of pounds, although the accuracy was not much greater than tenths. In the density tests, the materials were weighed directly in the mixing pan placed upon the platform of the scales. The water was usually weighed in a 16-qt. galvanized-iron pail.

Measuring.—For measuring the volume of concrete made in the volumetric tests, an old cast-iron air-brake cylinder and piston was found convenient. The cylinder was 8-in. in diameter, inside measurement, flanged at both ends, with a blank flange bolted to it, thus forming a vessel 8 in. in diameter and 9 in. deep. This vessel was calibrated carefully, and its contents calculated accurately for each unit of depth. After placing the concrete in the cylinder, the piston plunger was pressed down upon it until its bottom surface coincided exactly with the surface of the concrete. The depth of the concrete was then determined, and from this depth its volume was readily calculated.

A larger cylinder, 12 in. in diameter and 18 in. deep, was made for volumetric tests of materials containing large sized stone, but comparative tests with this and the smaller cylinder showed that the densities obtained by the two apparatus were so nearly identical that the larger one was not used to any great extent.

The materials were proportioned by mechanical analysis curves, as described in preceding paragraphs, and the weights of each diameter were scheduled from these curves. The mixing pan, which was about 2 ft. square, and 3 in. deep, was placed upon the scales, and any trowels and rammers or other apparatus to be used in the operation, and therefore to be more or less coated with cement, were placed in the pan, and the weight of this tare recorded on one of the beams. The aggregates, beginning with those of the finest diame-

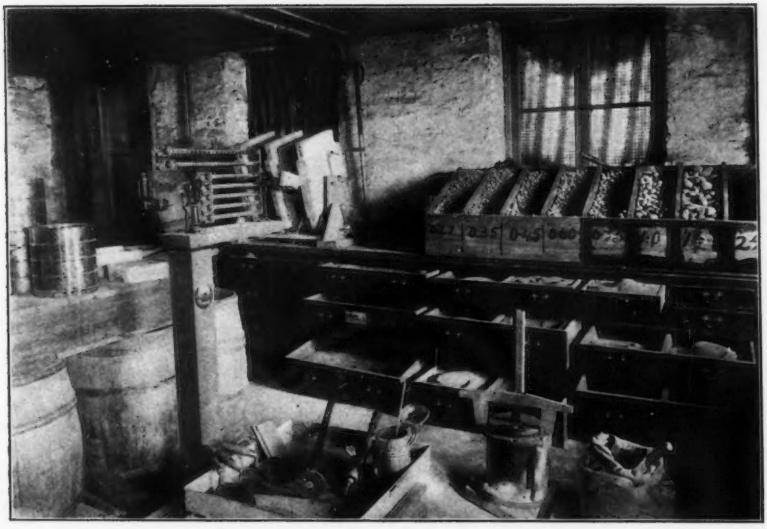


FIG. 1.—APPARATUS USED IN VOLUMETRIC TESTS.



FIG. 2.—IMPLEMENTS USED IN MAKING BEAMS.

ter, were then weighed. The schedule of weights of the aggregate was made up so that each weight included the weight of all the finer aggregates. In this way the weighing poise was reset for each size of material, and the materials were placed in the pan, one on top of the other. The cement was weighed last, so as to be on top of the other materials.

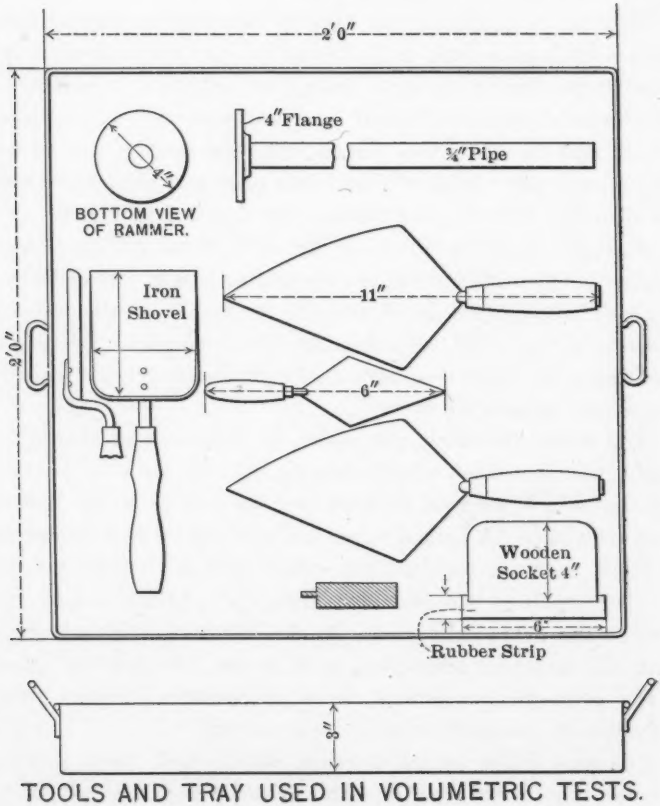
Mixing.—The mixing was done by two men working on opposite sides with large trowels and turning the dry material until it was of uniform color, in the same manner as concrete is turned by hand. The material was then formed in a ring, water was poured into the center, and the mass was turned until the mixing was thorough. The mixing pan, trowels, shovel (in plan and elevation), cleaner (in plan and section), and rammer are sketched in Fig. 2.

Because of the variation in the sizes of the grains of the aggregate in the different volumetric mixes, it was impossible to select a definite percentage of water to be used in all the tests, or to select in advance definite percentages for each mix. The mixtures containing the largest quantities of very fine material required the largest percentages of water.

The water, therefore, was added by judgment to obtain a soft mushy mixture which would scarcely hold its form in the mixing pan, but which was not so fluid that the mortar would run away from the stones. A pail of water, with its dipper, was first weighed, as much water as required was added, and the weight of the remaining quantity was deducted from the original weight to determine the net weight used. As the surplus water was removed from the specimen after placing it in the cylinder, the quantity finally given in the density sheets represents the water actually contained in the specimen as it began to set.

Ramming.—The mixed concrete which had been previously weighed, was introduced into the cylinder and rammed in 2-in. layers. This frequent ramming was necessary because of the small size of the receptacle, the friction on the sides preventing the material from settling even with very wet mixtures if ramming was delayed until the entire amount, which averaged a little over 6 in. in thickness, was placed. The rammer which was found best was a cast-iron disk, about 4 in. in diameter, with an upright handle, shown in Fig. 2.

A mixture of the consistency described above gave the best results in the cylinder. If too dry, there was always a possibility of occasional large air voids, and it was more difficult to manipulate, although the resulting rammed volume was about the same as the mushy mix which was used. A very wet mixture did not work



TOOLS AND TRAY USED IN VOLUMETRIC TESTS.

FIG. 2.

quite as well as either the mushy or the dry mixtures, the mortar probably not being in a sufficiently plastic condition to lubricate the stones. Rather curiously, a very wet mixture required more fine material to fill the voids than the others.

Removing Surplus Water.—As the concrete was rammed, the surplus mortar, if there was any, rose to the surface, and the water

separated, forming a layer from $\frac{1}{8}$ to $\frac{1}{4}$ in. in depth. After this had become clear, it was removed by a small suction pump, the weight being deducted from the weight of the water used in the mix.

Final Weighing.—The cylinder containing the concrete was weighed, as a check upon the weights of the dry material and the water; the mixing tray, together with the tools, was weighed, and the quantity of material adhering to them was thus found, being the difference between this weight and the weight of the clean tray and tools. The weight of the portion of the mix adhering was introduced into the final calculations, as described below.

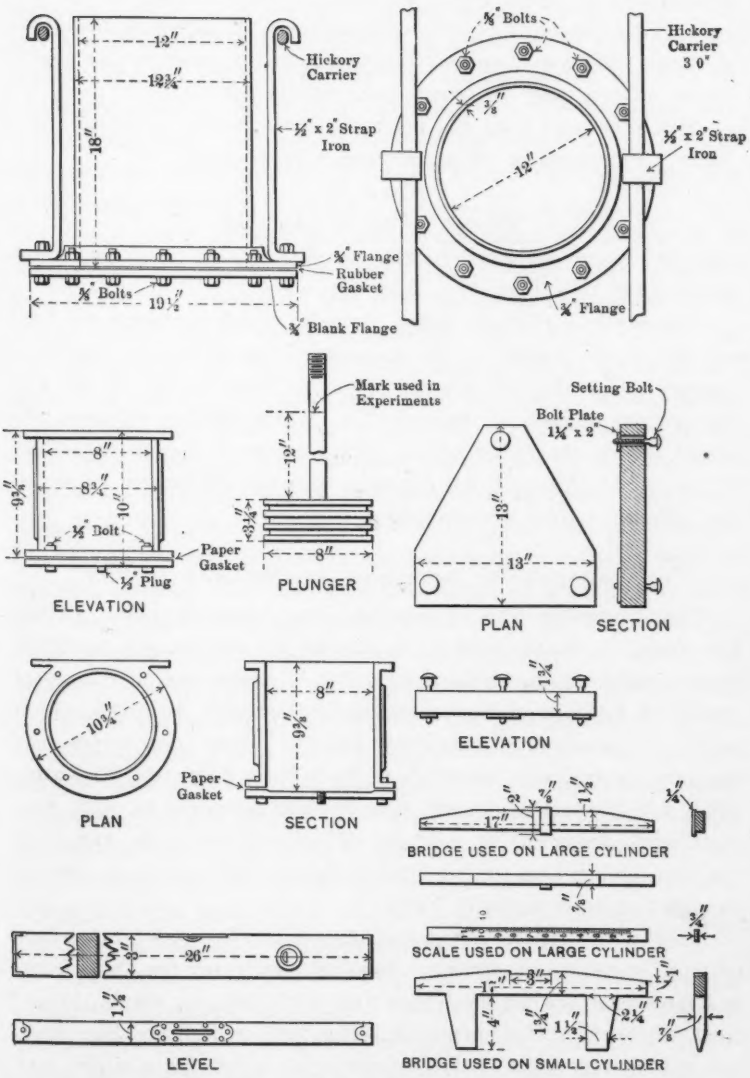
Measurement.—After the surplus water was removed, care was taken to see that the surface of the concrete was level, with no projecting stones, and the cylinder was leveled by placing it upon a tripod consisting of a board with three lag screws for legs. The piston was introduced and pressed firmly down, but not with sufficient force to disturb the mortar on top and thus force it up between the piston and the side of the cylinder. The wooden yoke was placed in position, and the depth of the concrete in the cylinder was measured by taking the height from the top of the yoke to a mark on the piston. The cylinder, piston, yoke, scale and magnifying glass are shown in Fig. 3. The test was now complete and ready for computation, the records having been entered upon the blank form, Table 3. The concrete was thrown away, and the tools were cleaned, ready for the next experiment.

Recording and Computing Data.—The form for recording the data in the volumetric tests of concrete—Table 3—is given with a typical test of Cowe Bay material recorded upon it, the observed and calculated figures being in italics. It is arranged so that all the weights may be entered in the laboratory, and the column of items also gives the constants to be used in calculation and the method of combining the various items so that the calculation of each sheet may be made by rote by an unskilled computer. The experiments in each class were numbered consecutively, for convenience in reference. The items recorded in the laboratory were the weights, and the depths of the piston in the cylinder—Items 1 to 17, 24, and 34 to 40. The figures following many of the items refer to the numbers of other items; the fraction following Item 19 represents, for example, the portion of the mix adhering to the tray and tools

TABLE 3.—FORM FOR RECORDING VOLUMETRIC TESTS.

1.	No.		377½
2.	Date		3/10/05
3.	Nominal Mix		
4.	Kind of Cement		Giant No. 20.
5.	Weight		2.65
6.	Wt. of Aggreg. finer than *0.0071*		0.85
7.	" " " coarser " "		21.50
8.	" " Vessel + Water (1)		29.00
9.	" " " " (2)		27.40
10.	" " Water Used		1.60
11.	Total Wt. Mixed		26.60
12.	Wt. of Tray + Tools (2)		13.15
13.	" " " " (1)		13.08
14.	" " Mixed Adhering		0.07
15.	" Syringe + Water		2.62
16.	" Syringe		2.60
17.	" Free Water		0.02
18.	Net Mix Set = 11 − 14 − 17		26.51
19.	Water left on Tray $\frac{10 \times 14}{5+6+10}$		0.02
20.	Net Water Set = 10 − 17 − 19		1.58
21.	Net Cement " $= 5 - \frac{5 \times 14}{5+6+10}$		2.61
22.	" Aggreg. finer than *0.0071* $= 6 \times \frac{6 \times 14}{5+6+10}$		0.84
23.	Net Aggreg. coarser than *0.0071*		21.50
24.	Depth of concrete in Cylinder, in		5.99
25.	Vol. of concrete in Cylinder, in.. *0.0393* × 24 − *0.001*		0.174
26.	Net Water per cu. ft. as mixed $\frac{10}{25}$		9.2
27.	" " " " " " set $\frac{20}{25}$		9.1
28.	" Cement " " " " " $\frac{21}{25}$		15.0
29.	" Aggreg. " " " " " $\frac{22+23}{25}$		128.4
30.	Abs. Vol. Water per cu. ft. as set $\frac{27}{62.4}$		0.146
31.	" " Cement " " " " " $\frac{28}{194}$		0.077
32.	" " Aggreg. " " " " " $\frac{29}{165}$		0.778
33.	" " Total 30 + 31 + 32		1.001
34.	Wt. of Form + Concrete		77.23
35.	" " Form		50.75
36.	" " Concrete		26.48
37.			
38.	Temp. of Water		46°
39.	Time of Mixing after Wetting		
40.	Remarks on Consistency		

REMARKS.—*Looked little stony in mix. Top surface filled. No excess of mortar on top. Small stones. No. 10 right under top surface.*



APPARATUS USED IN VOLUMETRIC TESTS.

FIG. 3.

which is water. The assumption is made—the fact having been determined by experiment—that the mortar sticking to the tray and tools consists of cement and particles of aggregate finer than diameter 0.0071, and water. The weight of the water in this mortar which adheres may be found from the proportion:

Mix adhering: total fine mortar = water in mix adhering: total water. Expressed in item numbers, this becomes:

$$\text{Item } 19 = \frac{\text{Item } 14}{\text{Item } 5 + \text{Item } 6 + \text{Item } 10} \times \text{Item } 10.$$

The net water contained in the concrete is thus Item 20, which equals Item 10—(Item 17 + Item 19).

The absolute volumes, Items 30 to 32, which represent the total volume of the liquid, or the volumes of the grains of cement or aggregate, are the net volumes per cubic foot divided by the specific gravity of each of the materials. These absolute volumes represent simply the ratios of the actual volumes of each ingredient to the total volume of the concrete, and are the figures by which the different mixes are compared.

Proportioning the Ingredients for Maximum Density.

The volumetric tests of concrete were begun in 1904. In the first place, it was the aim to determine, for the various materials under consideration, artificial mixtures of aggregates, of diameters graded by methods of mechanical analysis already described, which would give concrete of maximum density. These ideal mixes having been determined, the concrete made from them could be compared with respect to density, strength and permeability, with concrete made from simple mixtures of natural materials, and thus the best proportions to use with different materials upon actual construction work could be fixed.

Most of the experiments were made upon the same proportions of total aggregate to cement. The tests with Jerome Park stone and screenings for the most part were with 10%, by weight, of cement to the total dry materials. The tests with Cowe Bay sand and gravel were with similar proportions, except for a slight correction for the difference in specific gravity in order that the ratios of absolute volumes might be the same. In the earlier tests, mechanical analysis mixtures were made to definite curves, such

as parabolas and straight lines and curves intermediate between these, in order to select the curve giving the maximum density. In the later tests, in the winter of 1904-05, the methods were changed slightly, and the best results were obtained by making mixtures on trial curves without reference to their mathematical equations, and then, having found the best curves, equations were fitted to them, so that they could be more easily applied to different materials and more readily plotted.

All the earlier density specimens were found to be inferior to the tests made at Little Falls. Subsequent results in the manufacture of the beams indicated that this was due to the quality of the cement, reference to which has already been made. From the volumetric tests, and from tests of the composition of beams of neat cement, it appeared that the difference in the density was due to the cement taking so much water in gauging that the volume of the paste was increased, and the density lowered. In the winter of 1904-05 the experiments were continued with the cement which was then being furnished, and this gave satisfactory results. To avoid duplication of tests, and reach conclusions as speedily as possible, the first series of experiments, in the winter of 1904-05, was made with one class of material, broken stone and screenings excavated from Jerome Park Reservoir site, and with 10% of cement, by weight, of total dry material. This was followed by tests with Cowe Bay gravel and sand, and with other percentages of cement.

Necessity for Using Cement in Density Tests.—The necessity may be questioned for using cement in the tests for density, which were really for the purpose of determining the best proportions of the various sizes of particles of the aggregate. Why would it not have been simpler to use only the dry aggregate with no cement or water, and thus more readily obtain the mixtures which would give the least volume with the same weight?

As a matter of fact, both theory and experiment prove that the mixtures of aggregate which give the greatest density when dry do not necessarily give the greatest density when mixed with the cement and water. The cement and water actually occupy space in the mass, as many of the voids are too small for the grains of cement to fit into them without expanding the volume, and the water surrounds the grains of fine sand and cement, and actually increases

the bulk. As an illustration of this, the weight per cubic foot of very fine sand when loose, if weighed absolutely dry, is very nearly the same as the weight per cubic foot of a very coarse sand weighed dry. However, if the two sands are mixed with cement and water, the resulting mortar made with the fine sand will occupy a bulk perhaps 20% greater than the mortar of coarse sand, even when each of them is mixed with the cement in the same proportion by weight or by absolutely dry volume. The density of the mortar of fine sand will be correspondingly less than the mortar of coarse sand. Furthermore, the proportion of cement to sand affects the relative bulk and density of the two mortars, 1 : 1 mixtures giving different comparative results from 1 : 4 mortars.

If fine aggregate, having grains of the same size as cement particles, were used, the aggregate could have been mixed with water without using any cement, and the resulting density would probably have been the same as where real cement replaced the fine aggregate. However, this fine aggregate is more costly than cement because of the labor required to screen it. Moreover, the conditions would not have been so practical as where cement itself is used.

Density Tests with 2¼-in. Jerome Park Stone.—In all these tests, the cement was included in the mechanical analysis curve. This was in accordance with the assumption, which was afterward proved to be correct, that the grains of cement acted similarly to grains of sand of similar size as far as the density was concerned. A trial mechanical analysis curve was drawn, based on previous tests, and a volumetric test was made to determine the density. The curve was then altered in various ways by raising and lowering it at different diameters of stone, and volumetric tests were made with each experimental curve. By this means the general principles of the density of mixtures of Jerome Park broken stone and screenings with 10% Giant Portland cement were studied.

The curve which gave the best result when using a graded coarse aggregate with the cement was found to be one resembling a parabola in appearance, but, more strictly, consisting of a curve having for the lower portion the form of an ellipse, and above this a straight line running to 100% on the maximum diameter of the stone, in this case 2¼ in. The tangent point of the curve and straight line was at about 0.2 in. diameter. The curve started below measurable

diameters on the 7% line, indicating that at least 7% by weight of the very finest diameters of particles of cement or sand, or both, was required for a dense mixture.

In studying these density curves, the attention of the writers was called to experiments by Mr. A. E. Schutté, for the Warren Brothers Company, of Boston, on mixtures of aggregate to be used in their bituminous macadam pavement. For this class of work, which is really a scientifically graded concrete with bitumen for the matrix instead of cement, Mr. Schutté found the densest mixtures, and the best results in practice, to occur when a large percentage, about 50% in fact, of the aggregate consisted of stone of the coarsest diameter and of uniform size. Density tests, using a mixture of this kind, were made at Jerome Park for comparison with the tests with graded coarse stone. The resulting concrete was found to be slightly denser than the concrete with a graded stone. However, the mixture did not look as well in the mixing pan, and while, with a plastic substance like bitumen, a thorough mixture would without doubt produce excellent results, with the cement there seemed to be more of a tendency of the stones to separate from the mortar than with the concrete containing graded coarse stone. Whether or not these conclusions would apply in practice has not yet been determined. Tests of beams made with the two kinds of mixtures, although somewhat erratic, indicated a scarcely appreciable difference in the strength. Under some conditions, a stone of uniform size is as easy to obtain as a graded stone or "crusher run," hence further experiments are desirable in order to compare these two methods of mixture, and prove whether, under some conditions, the uniform stone may not be economical. The equations of the curve which was selected as the best are given in succeeding paragraphs.

Density Tests with 1-in. and ½-in. Stone.—The best analysis curve for cement and aggregates the maximum size of which was less than 2½ in. was next studied in a similar fashion, using, as before, 10% of cement to the weight of total dry materials. The curves for the smaller stone were found to resemble the 2½-in. curve, except that the tangent began at a smaller diameter. This diameter, where the curve ended and the straight line began, was found to be about one-tenth of the diameter of the maximum size of stone

used in the mixture; thus, for 1-in. stone, the tangent point was at about 0.1 in. diameter, and for ½-in. stone, the tangent point was at about 0.05 in. diameter. This suggested the possibility of a curve for all sizes of stone with the same equation, but with the diameter of the maximum size as a function of one of the terms. It was found that the shape of the curve was not exactly the same for the different sizes, but by introducing a small constant in the values of the axes of the ellipses, an equation was found which fitted all the diameters.

Cement versus Fine Sand.—The experiments just described assume that as far as density is concerned, cement acts in the same way as sand with grains of the same size. The cement, therefore, was included in making up the mechanical analysis curve. To prove this assumption, several other percentages, ranging from 8 to 15%, of cement to the weight of total aggregate, were tried, using the best curve already found for the mixtures with 10% of cement, and the resulting densities were substantially identical with the density of the mixture by the same curve using 10% cement. It is evident from this that correct proportioning for concretes of maximum density, but of different strength, consists in not simply increasing the percentage of cement, if a richer mixture is required, but in substituting more cement for a like absolute volume of sand having grains of the same size as the cement. In other words, the larger the proportion of cement, the fewer very fine grains of sand are required, because the cement takes the place of them in increasing the density.

Density Tests with Cowe Bay Material.—Tests of density of concrete composed of cement with gravel and sand from Cowe Bay were made in a similar manner to those of cement with Jerome Park stone and screenings. This investigation is of interest not only with reference to the work at Jerome Park, but to throw light on the mooted question of the relative value of broken stone and gravel, and form some basis for an economical comparison of the two in any given locality.

Tests were made with concrete composed of straight Cowe Bay material, that is, gravel and sand and cement, and with concrete of Jerome Park broken stone, Cowe Bay sand and cement. The best curves for both of these combinations were found to be similar to

the curves for concrete with straight Jerome Park material, except that, because of their rounded nature, the particles packed more closely together, so that similar mixtures gave with the Cowe Bay material a greater density, and for maximum density a smaller quantity of fine material was required, the curves in the diagram for Cowe Bay material being lower on the ordinate corresponding to one-tenth the maximum diameter of the stone. The combination of Jerome Park stone and Cowe Bay sand required more fine material than the Cowe Bay gravel and sand, but less than the Jerome Park stone and screenings.

Ideal Sand.—The character of the best or ideal sand does not appear to depend upon the shape of the coarse aggregate, the best sand for Jerome Park broken stone also being found best for the Cowe Bay gravel of the same sized grains, although less was required with the latter. On the other hand, the curve for the Jerome Park screenings (plus cement) was slightly different from the curve for Cowe Bay sand (plus cement), showing a different arrangement of grains.

Equations of Ideal Mechanical Analysis Curves of Density.

Having found by trial the curves for the best analyses of each size and class of material, mathematical curves were fitted to them for convenience in plotting. As already stated, all the curves for aggregate plus cement consist of ellipses with straight lines tangent to them. The curves all start upon and are tangent to the vertical zero axis of percentages at 7%—that is, at least 7% of the aggregate plus cement is finer than the No. 200 sieve—and run as ellipses with axes differing with the character of the materials, to a point which was found to be on a vertical ordinate or diameter the value of which is about one-tenth the diameter of the maximum particles of stone, and thence by a tangent to the ordinate of maximum diameter, intersecting this on the 100% abscissa.

The general equation of an ellipse, using its own axes, is

$$y = \frac{b}{a^2}\sqrt{a^2 - x^2}.$$

This is the simplest equation to use for plotting, as it is in regular form, and only the values of a and b (that is, the major and minor

axes) are required. Using zero co-ordinates on the mechanical analysis diagram, the equation becomes

$$(y - 7)^2 = \frac{b^2}{a^2}(a\,x - x^2).$$

The values of a and b found for the different materials, including the cement, are as follows:

Materials.	a	b
Jerome Park stone and screenings	$0.035 + 0.14\,D$	$29.4 + 2.2\,D$
Cowe Bay gravel and sand	$0.04 + 0.16\,D$	$26.4 + 1.3\,D$
Jerome Park stone and Cowe Bay sand	$0.04 + 0.16\,D$	$28.5 + 1.3\,D$

In this table, D = the maximum diameter of the stone, in inches.

It should be remembered that these experiments on density were on small laboratory specimens, thoroughly mixed, and carefully placed and compacted; and the values thus represent ideal conditions which must be modified for working conditions by increasing the value of b and thus adding more sand. Working formulas are given in Table 5.

Beam Tests.

While the experiments to obtain the laws of maximum density were in progress, during 1904, and before the results were available, a series of beams was made up with various proportions of Portland cement, Jerome Park screenings and Jerome Park crusher run stone, for the purpose of educating the men in handling the apparatus and making concrete. In this way 143 beams were made, and their strength and density determined. The results are given in Table 4. Owing to the peculiarity of the cement, to which reference has already been made, the breaking strengths are low, but the relative results agree closely with those at Little Falls.*

As soon as the results of the density tests were available in 1905, a series of beams was made up according to definite plans, to compare the strength of concrete made with different materials and different proportions of the various diameters of particles. Cement and aggregate, graded by curves of mechanical analysis which were found by the volumetric tests to produce concrete of maxi-

* The results at Little Falls may be found in Taylor and Thompson's "Concrete, Plain and Reinforced," pp. 258-9.

mum density for a given kind of material, were used as a basis for the tests. The strengths of these ideal specimens were then compared with the strengths of concrete mixtures proportioned by the artificial mechanical analysis curves which in the volumetric tests showed less density, to establish the general law that with the same percentage of cement the densest concrete is the strongest; the strengths of these ideal mixtures were compared with the strength of mixtures of natural material in ordinary proportions, and also in the best possible natural proportions; the relative strengths of concretes made with stone of different maximum sizes were compared; the relative strengths of concrete made with Jerome Park stone and screenings were compared with Cowe Bay gravel and sand and with Jerome Park stone and Cowe Bay sand; and the comparative strengths of neat cement and concrete beams made with different brands of cement were tested.

It was intended that two beams should be made from each mixture; each beam being manufactured separately, however, in order that the exact weights of materials entering into it could be determined. In certain cases it was found expedient to make only one beam of a mixture, but the results with these specimens were not as good, three transverse breaks and two compressive breaks not being sufficient to give a fair average of the material. The full list of tests, of which there were 116 specimens in all, are briefly scheduled as follows:

Straight Jerome Park material, using, respectively, 2¼-in., 1-in. and ½-in. stone, mixed with screenings and 10% cement, by weight, to total dry materials, and graded to the best ideal curves for each size, and to other artificial curves having more sand and less stone than the ideal.

Straight Jerome Park material, using, respectively, 2¼-in., 1-in. and ½-in. stone, mixed with screenings and cement in three natural proportions—1 : 2½ : 6½, 1 : 3 : 6, and 1 : 3½ : 5½.

Straight Jerome Park material, using for the coarse aggregate, stone of uniform size, 2¼-in., 1-in. and ½-in. diameter, respectively, mixed with screenings and 10%, by weight, of cement, this fine material being graded to an ellipse.

Straight Jerome Park material, 2¼-in. stone and screenings, mixed to the best ideal curve with 8, 12½ and 15% cement to total weight of dry materials.

TABLE 4 *(Continued).*

3.4	1:1	:2	34.0	34.0	68.2	136.2	15.6	151.8	138.9	151.2	0.175	0.192	0.392	0.584	0.759	0.250	1.009	0.186	0.055	0.241	112	6	550	385	479
7.8	1:1	:3.5	25.6	25.6	89.6	140.8	13.3	154.1	142.8	153.8	0.132	0.145	0.515	0.660	0.792	0.213	1.005	0.141	0.067	0.208	112	6	562	323	433
35.36	1:1	:5	20.8	20.8	104.1	145.7	12.8	158.5	147.4	156.7	0.107	0.118	0.598	0.716	0.823	0.205	1.028	0.114	0.063	0.177	112	6	315	218	278
84.85	1:2	:0	36.6	73.0	.....	109.6	26.3	135.9	112.5	134.5	0.189	0.412	.....	0.4 2	0.601	0.422	1.023	0.201	0.198	0.399	112	6	500	437	461
47.48	1:2	:1.5	28.2	56.4	42.5	127.1	18.2	145.3	129.4	145.3	0.145	0.319	0.244	0.563	0.708	0.292	1.000	0.154	0.138	0.292	112	6	394	313	350
9.10	1:2	:3	20.2	40.4	60.5	121.1	13.3	134.4	122.7	141.1	0.104	0.228	0.348	0.576	0.680	0.213	0.893	0.111	0.209	0.320	112	6	378	133	307
19.20	1:2	:5	17.7	35.4	88.5	141.6	13.1	154.7	143.0	154.1	0.091	0.200	0.509	0.709	0.800	0.210	1.010	0.097	0.103	0.200	112	4	276	233	253
53.54	1:2	:5	17.6	35.2	87.6	140.4	13.2	153.6	141.8	153.3	0.091	0.199	0.503	0.702	0.793	0.212	1.005	0.097	0.110	0.207	112	4	216	134	184
135.136	1:2	:5	17.6	35.2	87.9	140.7	14.3	155.0	142.1	153.5	0.091	0.199	0 505	0.704	0.795	0.229	1.024	0.097	0.108	0.205	120	5	354	222	308
37.38	1:2	:7.5	13.8	27.6	103.8	145.2	11.9	157.1	146.3	156.2	0.071	0.156	0.597	0.753	0.824	0.191	1.015	0.076	0.100	0.176	112	4	315	197	249
69	1:3	:0	28.2	84.6	.....	112.8	23.4	136.2	115.1	136.3	0.145	0.478	.....	0.478	0.623	0.375	0.998	0.154	0.223	0.377	56	3	281	254	271
70	1:3	:0	....	....	.....	....	....	.....	.....	.....	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	28	2	242	211	226
121.122	1:3	:0	27.4	82.4	.....	109.8	24.5	134.3	112.0	134.3	0.141	0.466	.....	0.466	0.607	0.393	1.000	0.150	0.243	0.393	84	6	324	292	306
49.50	1:3	:2	21.1	63.4	42.2	126.7	18.6	145.3	128.4	144.8	0.109	0.359	0.243	0.601	0.710	0.298	1.008	0.116	0.174	0.290	112	3	239	222	231
139.140	1:3	:4	16.7	50.0	66.7	133.4	17.0	150.4	134.7	148.9	0.096	0.282	0.383	0.665	0.751	0.273	1.024	0.092	0.157	0.249	120	5	304	190	254
15.16	1:3	:4	17.2	51.6	68.9	137.7	15.3	153.0	139.1	151.6	0.099	0.297	0.396	0.686	0.777	0.245	1.022	0.095	0.128	0.223	112	2	220	151	185
27.28	1:3	:4	17.1	51.3	68.4	136.8	15.1	151.9	138.2	151.1	0.088	0.290	0.393	0.683	0.771	0.242	1.013	0.094	0.135	0.229	112	1	130	130	130
51.52	1:3	:4	17.2	51.5	68.6	137.3	15.7	153.0	138.7	151.4	0.089	0.291	0.394	0.685	0.774	0.252	1.026	0.095	0.131	0.226	112	3	222	112	164
111	1:3	:4	16.4	49.1	65.5	131.0	16.9	147.9	132.3	147.3	0.085	0.277	0.376	0.653	0.738	0.271	1.009	0.091	0.171	0.262	112	2	211	135	173
127.128	1:3	:6	13.7	41.1	82.0	136.8	15.7	152.5	137.9	150.9	0.071	0.232	0.471	0.703	0.774	0.252	1.026	0.070	0.150	0.226	84	4	199	141	170
78	1:3	:6	13.9	41.7	83.4	139.0	15.4	154.4	140.1	152.3	0.072	0.236	0.479	0.715	0.787	0.247	1.034	0.077	0.136	0.213	56	2	90	76	83
79	1:3	:6	....	....	.....	....	....	.....	.....	.....	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	28	2	99	96	98
21.22	1:3	:7	12.9	39.0	90.8	142.7	13.1	155.8	143.7	154.6	0.067	0.220	0.522	0.742	0.809	0.210	1.019	0.071	0.120	0.191	112	4	177	147	160
55.56	1:3	:7	13.0	39.0	90.9	142.9	13.6	156.5	143.9	154.8	0.067	0.220	0.522	0.742	0.809	0.218	1.027	0.071	0.120	0.191	112	2	192	181	187
88.89	1:4	:0	21.9	87.4	.....	109.3	25.4	134.7	111.1	133.8	0.113	0.494	.....	0.494	0.607	0.407	1.014	0.120	0.273	0.393	112	6	274	209	225
94.95	1:4	:3	15.8	63.3	47.4	126.5	18.9	145.4	127.8	144.5	0.081	0.358	0.272	0.630	0.711	0.303	1.014	0.086	0.203	0.289	112	3	221	189	203
31.32	1:4	:6	12.5	50.2	75.3	138.0	15.1	153.1	139.0	151.7	0.064	0.284	0.433	0.717	0.781	0.242	1.023	0.068	0.151	0.219	112	5	166	120	144
118.119	1:4	:6	12.2	48.8	73.2	134.2	15.8	150.0	135.2	149.2	0.063	0.276	0.421	0.697	0.760	0.253	1.013	0.067	0.173	0.240	111	3	222	125	178
5.6	1:4	:6	12.6	50.4	75.4	138.4	15.3	153.7	139.4	151.9	0.065	0.285	0.433	0.718	0.783	0.245	1.02-	0.069	0.148	0.217	112	2	156	121	138
23.24	1:4	:9	10.0	40.0	90.0	140.0	15.7	155.7	140.8	152.8	0.052	0.226	0.517	0.743	0.795	0.252	1.047	0.055	0.150	0 205	112	1	63	63	63
57.58	1:4	:9	10.3	41.4	93.0	144.7	13.7	158.4	145.5	155.9	0.053	0.234	0.534	0.768	0.821	0.220	1.041	0.056	0.123	0.179	112	1	154	154	154
116.117	1:4	:9	10.0	39.9	89.7	139.6	15.1	154.7	140.4	152.5	0.052	0.225	0.516	0.741	0.793	0.242	1.035	0.055	0.152	0.207	111	1	128	128	128

TABLE 4.—COMPOSITION AND TRANSVERSE STRENGTH OF CONCRETE BEAMS MADE OF GIANT PORTLAND CEMENT, JEROME PARK SCREENINGS, AND RUN OF CRUSHER JEROME PARK STONE, $\frac{1}{10}$ INCH TO $2\frac{1}{4}$ INCHES IN DIAMETER.

Beams, 6 by 6 by 72 in. Spans, 30 and 60 in.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)
Reference numbers.	Proportions, by weight.	Weight, in Pounds, of Material in 1 Cu. Ft. of Beam, as Mixed.					Totals.			Calculated Volume, in Cubic Feet, of Material in 1 Cu. Ft. of Beam, as Mixed.							Volume of Voids in 1 Cu. Ft.			Modulus of Rupture.				
	C. S. G.	Cement.	Sand.	Stone.	Total dry mix.	Water.	As mixed.	Minimum.	Maximum.	Cement.	Sand.	Stone.	Total sand and stone.	Total dry.	Water.	Total.	Cement.	Aggregate.	Total.	Age, in days.	No. of breaks.	Pounds per square inch. Maximum.	Minimum.	Average.
73	1: 0 : 0	93.7	....	.....	93.7	31.2	124.9	101.2	125.9	0.483	.....	.....	.....	0.483	0.500	0.983	0.517	.....	0.517	83	3	518	386	442
120	1: 0 : 0	93.5	....	.....	93.5	31.8	125.3	101.0	125.7	0.482	.....	.....	.....	0.482	0.510	0.992	0.518	.....	0.518	111	3	917	896	906
143	1: 0 : 0	94.7	....	.....	94.7	32.3	127.0	102.3	126.9	0.488	.....	.....	.....	0.488	0.518	1.006	0.512	.....	0.512	119	3	963	935	946
13.14	1: 0 : 0.8	67.6	....	54.1	121.7	20.5	142.2	127.1	143.0	0.348	.....	0.311	0.311	0.659	0.329	0.988	0.371	0.030	0.341	112	6	664	570	629
17.18	1: 0 : 1.7	49.6	....	84.2	133.8	16.7	150.5	137.8	150.0	0.256	.....	0.484	0.484	0.740	0.268	1.008	0.273	0.013	0.260	112	6	652	492	556
29	1: 0 : 2.5	40.6	....	101.3	141.9	14.5	156.4	145.1	154.9	0.209	.....	0.582	0.582	0.791	0.232	1.023	0.223	0.014	0.209	56	3	384	363	371
30	1: 0 : 2.5	....	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	28	2	357	309	329
125,126	1: 0 : 2.5	39.4	....	98.4	137.8	15.2	153.0	141.0	152.2	0.203	.....	0.556	0.556	0.769	0.244	1.013	0.216	0.015	0.231	84	6	562	415	461
43.44	1: 0.5: 0.5	59.6	29.8	29.8	119.2	21.6	140.8	124.0	141 3	0.307	0.168	0.171	0.339	0.646	0.346	0.992	0.327	0.027	0.354	112	6	618	547	579
33.34	1: 0.5: 3.7	27.9	14.0	103.3	145.2	12.7	157.9	147.4	156.6	0.144	0.079	0.594	0.673	0.817	0.204	1.021	0.153	0.030	0.183	112	6	411	338	386
82.83	1: 1 : 0	54.6	54.6	.....	109.2	25.5	134.7	113.6	134.8	0.281	0.308	.....	0.308	0.589	0.409	0.998	0.299	0.112	0.411	112	6	612	553	586
45.46	1: 1 : 1	42.5	42.5	42.5	127.5	18.4	145.9	130.9	146.0	0.219	0.240	0.244	0.484	0.703	0.295	0.998	0.233	0.064	0.297	112	6	522	437	484

TABLE 4 (*Continued*).

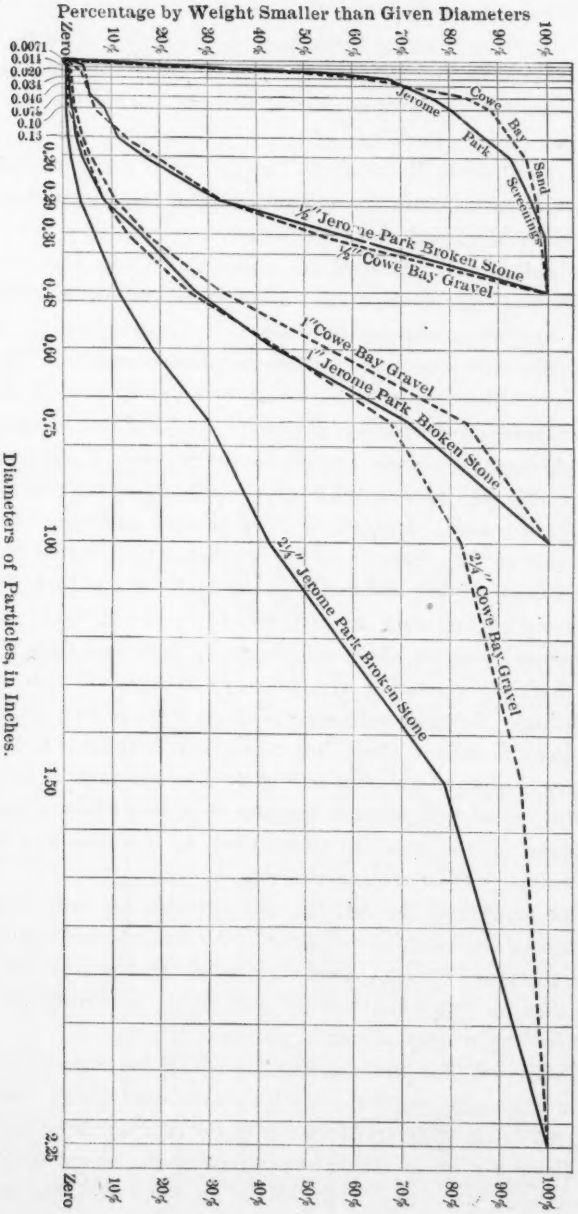
(1)	(2)			(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)
				Weight, in Pounds, of Material in 1 Cu. Ft. of Beam, as Mixed.								Calculated Volume, in Cubic Feet, of Material in 1 Cu. Ft. of Beam, as Mixed.							Volume of Voids in 1 Cu. Ft.			Modulus of Rupture.				
Reference numbers.	Proportions, by weight.			Cement.	Sand.	Stone.	Total dry mix.	Water.	Totals.			Cement.	Sand.	Stone.	Total sand and stone.	Total dry.	Water.	Total.	Cement.	Aggregate.	Total.	Age, in days.	No. of breaks.	Pounds per square inch.		
	C.	S.	G.						As mixed.	Minimum.	Maximum.													Maximum.	Minimum.	Average.
90.91	1: 5	: 0		18.6	93.0	.....	111.6	23.2	134.8	113.1	135.2	0.096	0.525	.....	0.525	0.621	0.372	0.993	0.102	0.277	0.379	112	3	211	115	164
76	1: 6	: 0		15.5	93.4	.....	108.9	26.1	135.0	110.1	133.4	0.080	0.528	.....	0.528	0.608	0.418	1.026	0.085	0.307	0.392	56	3	170	95	125
77	.....			.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	28	2	82	48	65
123.124	1: 6	: 0		15.4	92.5	.....	107.9	25.2	133.1	109.1	132.7	0.079	0.523	.....	0.523	0.602	0.404	1.006	0.084	0.314	0.398	84	4	208	145	175
11.12	1: 6	: 7		9.3	56.0	65.3	130.6	15.5	146.1	131.3	146.9	0.048	0.316	0.375	0.691	0.739	0.248	0.987	0.051	0.210	0.261	112	3	89	39	66
59.60	1: 6	: 7		9.6	57.5	67.2	134.3	16.4	150.7	135.0	149.2	0.050	0.325	0.386	0.711	0.761	0.263	1.024	0.053	0.186	0.239	112	1	114	114	114
112.113	1: 6	: 7		9.4	56.4	65.8	131.6	17.8	149.4	132.4	147.5	0.049	0.319	0.378	0.697	0.746	0.285	1.031	0.052	0.202	0.254	112	4	116	88	104
65	1: 6	: 12		7.5	45.1	90.3	142.9	14.7	157.6	143.5	154.6	0.039	0.255	0.519	0.774	0.813	0.236	1.049	0.042	0.145	0.187	56	1	50	50	50
66	.....			.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	28	2	58	51	55
25.26	1: 6	: 12		7.6	45.8	91.6	145.0	14.3	159.3	145.6	156.0	0.039	0.259	0.526	0.785	0.824	0.229	1.053	0.042	0.134	0.176	112	1	72	72	72
114.115	1: 6	: 12		7.2	43.5	86.8	137.5	15.1	152.6	138.1	151.1	0.037	0.246	0.499	0.745	0.782	0.242	1.024	0.039	0.179	0.218	111	1	115	115	115
107.108	1: 8	: 0		11.9	95.4	.....	107.3	26.4	133.7	108.2	132.3	0.061	0.539	....	0.539	0.600	0.423	1.023	0.065	0.335	0.400	112	4	162	73	127

Volumes, in cubic feet per 100 lb. as mixed: Cement, 1.00; Sand, 1.06; Stone, 1.03. Specific Gravity: Sand, 2.81; Stone, 2.785; Cement, 3.09. Weights, in pounds per cubic foot, as mixed: Cement, 100; Sand, 94.8; Stone, 97.0; Water, 62.4.

Tensile strength of cement, in pounds per square inch, neat: 7 days, 536; 28 days, 574; 6 months, 688.

Mechanical analyses; percentage by weight of particles, below diameter: Sand, 100%, 0.60; 93%, 0.20; 81%, 0.10; 66%, 0.34; 48%, 0.016; 21%, 0.0071; 2%, 0.0027. Stone, 100%, 2.25; 42%, 1.00; 11%, 0.48; 1%, 0.10.

Column 9 = Column 3 × 0.08 + Column 6. Column 10 = Column 6 + (Column 20 × 62.4). Column 9 represents the theoretical minimum, assuming 8% of water for chemical combination. Column 10 represents the theoretical maximum, assuming that the voids are filled with water.



AVERAGE MECHANICAL ANALYSES OF VARIOUS NATURAL MATERIALS.

FIG. 4.

Straight Cowe Bay material, using, respectively, 2¼-in., 1-in. and ½-in. gravel, mixed with Cowe Bay sand and 10% cement, by weight, and graded to the best ideal curve for each size; also, in natural proportions, 1 : 3 : 6; and also to a curve identical with one of the straight Jerome Park curves.

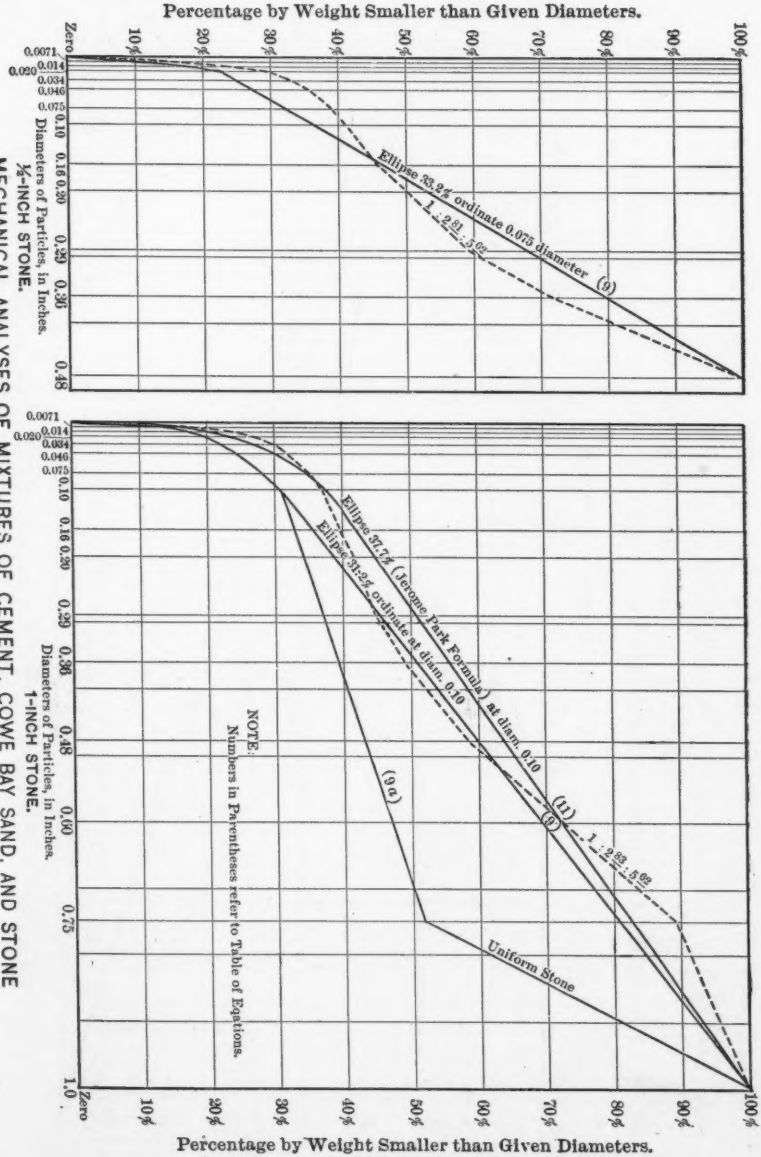
Straight Cowe Bay material, using 2¼-in. and 1-in. stone of uniform size, mixed with Cowe Bay sand and 10%, by weight, and this fine material graded to an ellipse.

Mixed Jerome Park broken stone and Cowe Bay sand, using, respectively, 2¼-in., 1-in. and ½-in. stone, mixed with Cowe Bay sand, and 10% cement, by weight, and graded to the best ideal curve for each size; also, in natural proportions, 1 : 3 : 6; and also to a curve identical with one of the straight Jerome Park curves.

Methods of Preparing Materials for Natural Proportions.—A few mixtures were made in ordinary proportions, 1 : 2½ : 6½, 1 : 3 : 6, and 1 : 3½ : 5½, as scheduled previously, for comparison with the ideal proportions. Instead of using for the aggregates the natural materials as they came from the crusher, which varied from day to day because of the difference in methods of handling and in the character of the stone in different parts of the ledge, an average mechanical analysis of the screenings as they came from the crusher was made by averaging a number of analyses of different lots of screenings. Average analyses of Jerome Park broken stone, of Cowe Bay gravel, and of Cowe Bay sand, were similarly found. These average analyses are shown in Fig. 4. The analyses of the two materials which were to be used together were plotted on a diagram and combined in the required proportions by the ordinary method of combining mechanical analysis curves.

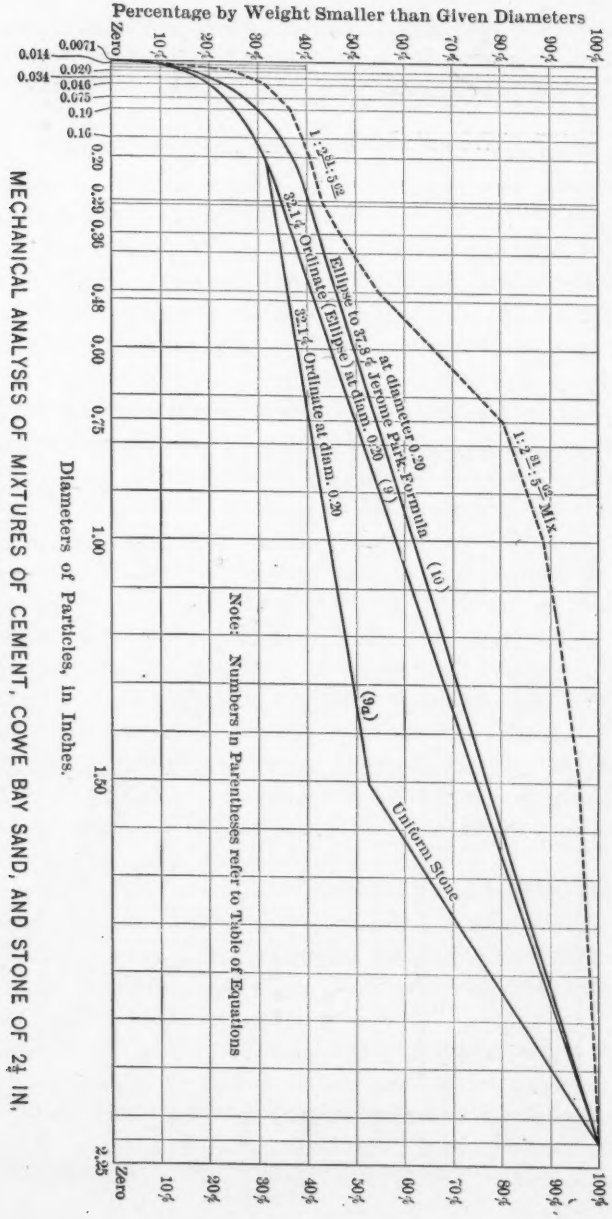
The weights of the various-sized particles for each of the beams, which were graded to so-called natural mixtures, were obtained from these combined curves. This eliminated the variation in the materials coming from the crusher and from the dredge on different days, and gave truly average mixtures.

Mechanical Analysis Curves Used.—All the mechanical analyses of the aggregate and cement which were used in the concretes for the 1905 beam tests are drawn to scale in Figs. 5 to 10, inclusive, and Table 5 gives in full the equations of all the curves of artificial mixes which were used. The curves are numbered, and correspond-



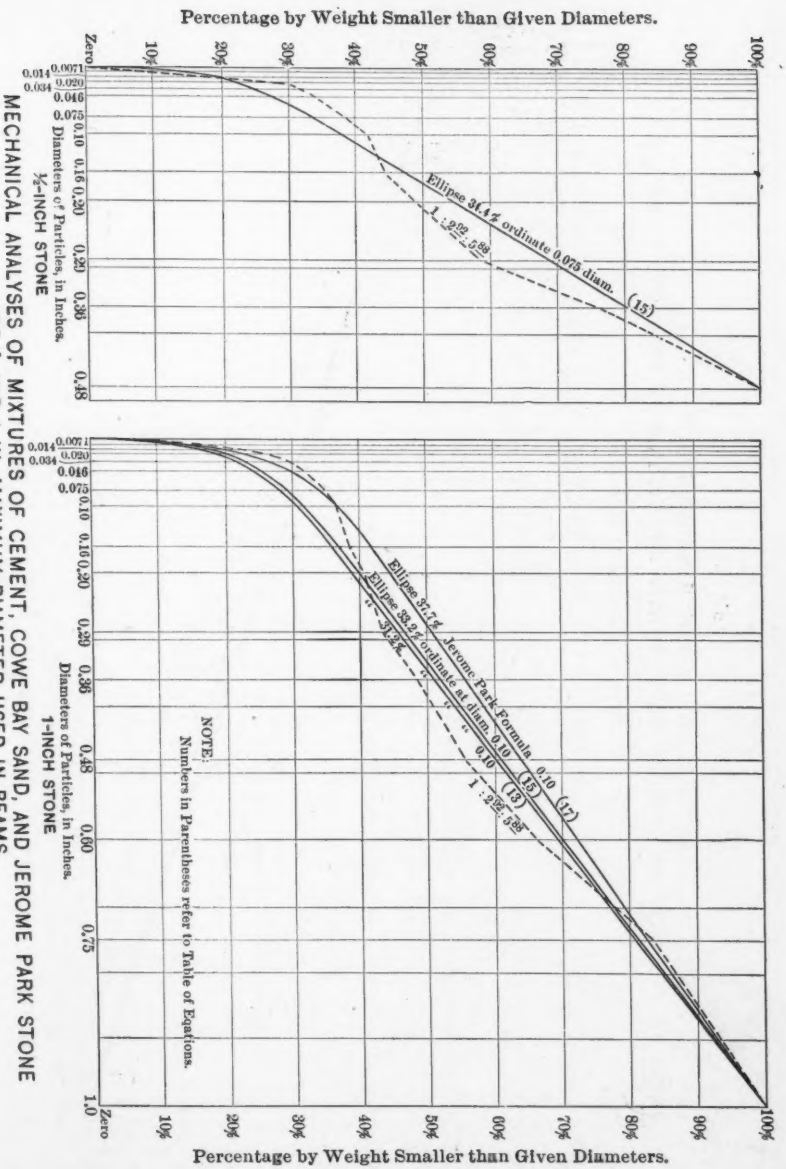
MECHANICAL ANALYSES OF MIXTURES OF CEMENT, COWE BAY SAND, AND STONE OF ½ IN. AND 1 IN. MAXIMUM DIAMETER USED IN BEAMS.

FIG. 5.



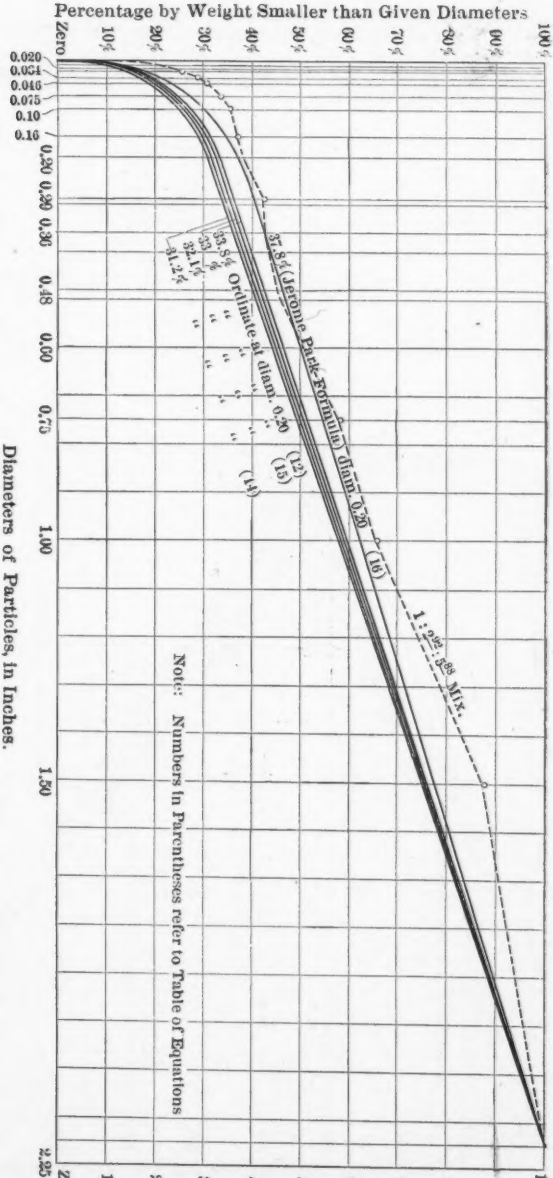
MECHANICAL ANALYSES OF MIXTURES OF CEMENT, COWE BAY SAND, AND STONE OF 2¼ IN. MAXIMUM DIAMETER USED IN BEAMS.

FIG. 6.



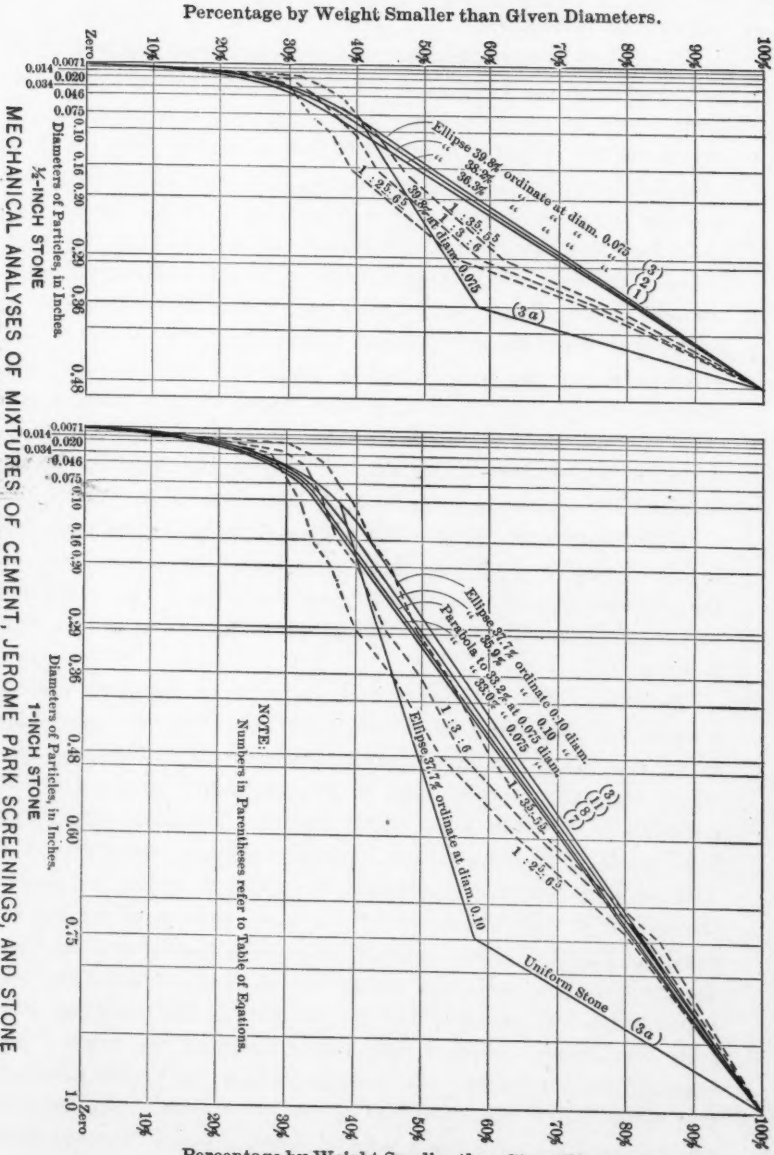
MECHANICAL ANALYSES OF MIXTURES OF CEMENT, COWE BAY SAND, AND JEROME PARK STONE OF ½ AND 1 IN. MAXIMUM DIAMETER USED IN BEAMS.

FIG. 7.



MECHANICAL ANALYSES OF MIXTURES OF CEMENT, COWE BAY SAND, AND JEROME PARK STONE OF 2¼ IN. MAXIMUM DIAMETER USED IN BEAMS.

FIG. 8.



MECHANICAL ANALYSES OF MIXTURES OF CEMENT, JEROME PARK SCREENINGS, AND STONE OF ¼ AND 1 IN. MAXIMUM DIAMETER USED IN BEAMS.

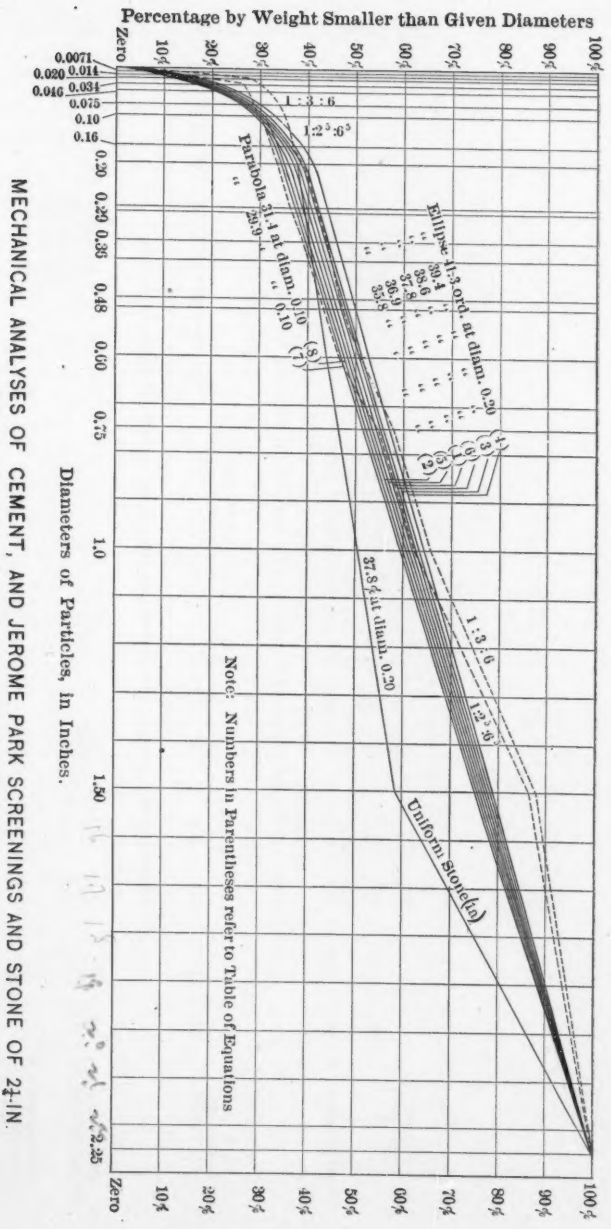
FIG. 9.

ing numbers are placed on the curves in the diagrams for convenience of reference.

It was found by experiment that more sand was required in the curves used in the beam mixtures than was indicated by the best ideal curves in the volumetric tests for density. Accordingly, the curves in the diagrams are all uniformly higher than would be expected from the density experiments. In some of the diagrams, a larger number of curves were drawn than would appear from the schedule to be needed. This was due to the fact just mentioned. The first mixtures were made with curves corresponding to the best curves of the density tests, and it was found necessary to raise all of them about 2% at the tangent point to prevent a very rough surface to the beam, which indicated that there was not sufficient mortar to fill the voids in the stone. In the table, which gives the full data of the beam tests, these specimens are designated in the remarks. The results from them, especially in the density tests, cannot be considered as entirely reliable.

Methods and Apparatus.—The method of weighing the materials for the beams and mixing them was similar to the processes in the volumetric tests for density just described. The tools and various implements used in making the beams are shown in Fig. 2, Plate XII.

Weighing.—The weight of each diameter of aggregate and of cement was calculated by direct proportion from the percentage curve, and the approximate quantity of water to be used was estimated from the quantity used in the volumetric tests made with materials of the same mechanical analysis. The total quantity of dry materials varied appreciably with the maximum size of stone and with the character of the material. The larger the stone, the greater the weight of material required for a beam, because of the greater density. The Cowe Bay material has lower specific gravity than the Jerome Park stone and screenings, so that a less weight was required on this account, but the density of the resulting concrete was greater, so that this nearly balanced the other. The quantity for a mixture with 1 : 9 proportions by weight averaged about 220 lb. of aggregate and 25 lb. of cement. The weights actually used for each beam may be found directly from the data in Table 8.



MECHANICAL ANALYSES OF CEMENT, AND JEROME PARK SCREENINGS AND STONE OF 2¼-IN. MAXIMUM DIAMETER USED IN 1905 BEAM TESTS.

FIG. 10.

JEROME PARK SCREENINGS AND STONE GRADED TO PARABOLAS AND STRAIGHT LINE.

(7)	144, 145.	.....	$\frac{3\sqrt[3]{D}}{29}$	....	(22.9)	.....	(30)	.....	.....	Special curve (abandoned).
(8)	146, 147.	.....	$\frac{3\sqrt[3]{D}}{32}$	....	(24.4)	.....	(32)	.....	.....	Special curve (abandoned).

COWE BAY SAND AND STONE GRADED TO ELLIPSE AND TANGENT STRAIGHT LINE.

(9)	217, 229, 223, 226, 259, 224, 225, 233.	$0.04 + 0.16\,D$	$26.4 + 1.3\,D$	0.40	(29)	0.20	(28)	0.12	27	Ideal curve.
(10)	234.	$0.035 + 0.14\,D$	$29.4 + 2.2\,D$	0.35	(34)	.....	.....	.....	.....	Like curve (1)
(11)	235.	$0.035 + 0.14\,D$	$31.4 + 2.2\,D$	....	.....	0.175	(34)	.....	.....	Like curve (3)

JEROME PARK SCREENINGS AND COWE BAY STONE GRADED TO ELLIPSE AND STRAIGHT LINE.

(12)	213, 214, 216, 218.	$0.04 + 0.16\,D$	$28.5 + 1.3\,D$	0.40	(31)	0.20	(30)	0.12	29	Ideal curve.
(13)	201, 202.	$0.04 + 0.16\,D$	$26.5 + 1.3\,D$	....	(28)	0.20	(28)	.....	.....	
(14)	200.	$0.04 + 0.16\,D$	$25.5 + 1.3\,D$	0.40	.....	.....	.....	.....	.....	
(15)	209, 210, 211, 212.	$0.04 + 0.16\,D$	$27.5 + 1.3\,D$	0.40	(30)	0.20	(29)	0.12	28	
(16)	219.	$0.035 + 0.14\,D$	$29.4 + 2.2\,D$	0.35	(34)	.....	.....	.....	.....	Like curve (1)
(17)	215.	$0.035 + 0.14\,D$	$31.4 + 2.2\,D$	....	.....	0.175	(34)	.....	.....	Like curve (3)

TABLE 5.—EQUATIONS OF MECHANICAL ANALYSIS CURVES FOR PROPORTIONING CONCRETE BEAMS, IN 1905 TESTS.

Ellipses: (1), $(y - 7)^2 = \frac{b^2}{a^2}(2ax - x^2)$. (2), $y = + \frac{b^2}{a^2}\sqrt{a^2 - x^2}$.

Straight Line: $y = \frac{100 - y^1}{D - x^1}(x - x^1) + y^1$.

Parabola: $y = 7 + 100\sqrt{bx}$

a and b are axes of ellipses and parabolas, horizontal and vertical.

D is the diameter of the maximum-sized stone, in inches.

Curve number (see diagram).	Reference numbers of beams.	General Values.		Numerical Values.						Remarks.
				$D = 2\frac{1}{4}$.		$D = 1$.		$D = \frac{1}{2}$.		
		a	b	a	b	a	b	a	b	
	Jerome Park Screenings and Stone Graded to Ellipse and Tangent Straight Line.									
(1)	155, 157, 151, 152, 164, 165, 179, 180, 183, 184, 193.	$0.035 + 0.14D$	$29.4 + 2.2D$	0.35	(34)	0.175	(32)	0.105	(30)	Ideal curve.
(2)	148, 153, 154, 178.	$0.035 + 0.14D$	$27.4 + 2.2D$	0.35	(32)	.....	.....	0.105	(32)	
(3)	156, 158, 195, 196, 159, 160, 181, 182, 185, 186, 197.	$0.035 + 0.14D$	$31.4 + 2.2D$	0.35	(36)	0.175	(34)	0.105	(34)	
(4)	189, 190, 191.	$0.035 + 0.14D$	$33.4 + 2.2D$	0.35	(38)	.....	.....	.....	.....	
(5)	149.	.....	.....	0.45	(36.2)	.....	.....	.....	.....	Special curve (abandoned).
(6)	150.	.....	.....	0.45	(38.2)	.....	.....	.....	.....	Special curve (abandoned).

The can for receiving the material, about 18 in. in diameter and 2 ft. deep, was placed on the scale and the tare was recorded by the weigher. Beginning with the finest, two other men scooped the different sizes of aggregates, and also the cement, into the can, the poise being slid ahead for each size.

Mixing.—The dry material was then dumped upon the 5 by 8-ft. mixing platform, which was made of a plate of sheet iron surrounded by a strip of wood to prevent the soft material from overflowing. Four men turned the dry material with square-pointed shovels, just as hand-mixed concrete is turned in practice. Three turnings were given, dry. Then the mixture was formed into a circle, and the approximate quantity of water was weighed and turned into it. The material was then mixed wet by the four men, as in practice. Three turnings were given to it, to insure a uniform mix throughout the beam.

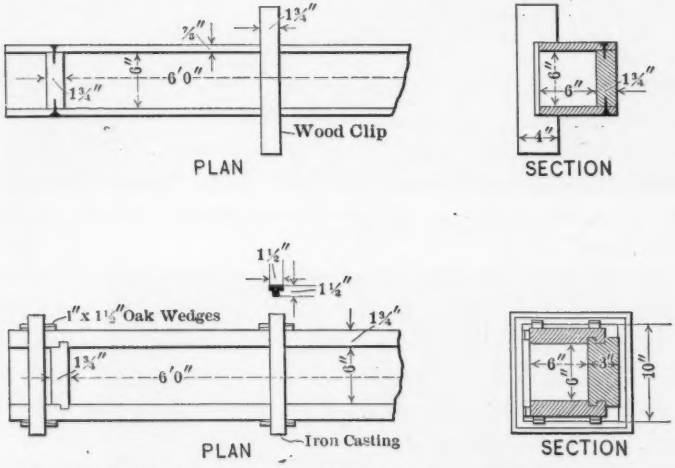
Consistency.—The required consistency was soft and mushy, but not wet enough for the mortar to run away from the stones, scoop shovels being necessary to handle the wet concrete. If the calculated weight of water was not sufficient to give the required consistency, more was added, and its weight recorded.

Marks for Specimens.—Four marks were embedded in each beam. The tags consisted of pieces of brass stamped by hand by a die, with the number of the beam followed by the letters, *A, B, C* and *D,* respectively. Each tag was about $1\frac{1}{2}$ in. long by $\frac{1}{2}$ in. wide, and had projections bent up from it to run into the concrete. They were definitely located in the bottom of the mould by measurement, so as to lie nearly, but not quite, in the center of each of the four pieces into which the beam was finally to be broken. Each tag was placed in the bottom of the mould, and held in place with the blade of a shovel until the concrete was poured around and on top of it. The tags were often slightly covered by thin mortar which ran under them, but, being exactly located, they were readily found by scraping the surface.

Placing in Moulds.—The mould for the beam, shown in Fig. 11, was weighed, and the concrete was shoveled into it, and placed and slightly compacted with the aid of large trowels and shovels. The blade of a shovel was generally thrust down by each face of the forms to insure a smooth surface, although this was not found

absolutely necessary. The mould with the concrete was weighed to obtain the weight of concrete green for the density determination, and placed on one side to set.

The quantity of material required had been calculated approximately from the volumetric tests. If any was left over, after the mould had been filled, it was weighed, and the proportion of this which was water was estimated. As the proportional amount of water may exert a difference of 2 or 3% upon the calculated density of the beam, it is suggested that in future tests the concrete left over be carefully separated from the excess of water, so as to



SKETCH OF MOULD USED FOR MAKING CONCRETE BEAMS.

FIG. 11.

have about the same consistency as the beam, and then weighed, while the water remaining, together with the free water from the surface of the concrete in the mould, be weighed separately and recorded. As this water contains some cement in suspension, its approximate specific gravity should be determined by a test, and this specific gravity should be used in the calculations of the density of the beams.

As soon as the concrete was hard enough to handle easily—usually in about 7 days—it was buried in moist sand, where it remained until it was tested.

TABLE 6.—FORM FOR RECORDING BEAM MIXTURE.

No. of Beam	*217*
Approx. Vol. of Beam	*1½ cu. ft.*
Date	*May 21, 1905.*
Hour	*1.30 P. M.*
Temp. air in cellar	*64°*
CEMENT.	
Kind	*Giant.*
Lot No.	*30.*
Wt., lbs.	*23.32*
AGGREGATE.	
Kind	*Cowe Bay.*
Analysis No.	*Ideal 36% ord.*
Wt., lbs.	*196.68*
WATER.	
Temp. F.	*54°*
Total used	*14.0*
Wt. of Form No. 14 empty	*131.25*
" " " " filled	*364.00*
" " Beam 217	*232.75*
Total Wt. mixed	*234.00*
Wt. of Mix left over	*0.00*
Total Wt. of Beam	*232.75*
Wt. unaccounted for	*1.25*
SIDES OF FORM REMOVED.	
Wt. of Form No. 14 filled	*359.75*
Beams buried—day, hour, days before burying	*3/26/04*
Loss of wt. in setting	7

Inspector, *W. H.*

Recording and Computing Data on Beams.—The method of recording the data for mixing is given in Table 6. The form is filled out, in italics, with a typical test, for illustration. When ready to break, after removing from the moist sand, measurements were taken for the purpose of calculating the density and the modulus of rupture.

As each beam was broken into four pieces, first in the middle, and then the two halves broken again, measurements were taken at the half and quarter points, also at the two ends, making five sections in all. At each section, three dimensions of depth and three of width were measured, each reading to hundredths of inches. From the beam mixing data and the calculated volume of the beam, the weights of the material in 1 cu. ft. of the beam and the absolute unit volumes, were calculated. The modulus of rupture for each break was calculated from the dimensions and the breaking weight.

Beam Testing Machine.—The machine for breaking the beams was made by Riehlé Brothers, of Philadelphia, and the method of loading it was improved in the laboratory. Fig. 1, Plate XIII, is a photograph of the machine with a beam in place ready to break. In order to avoid the negative moment due to overhanging portions of the beam, the bearings for each specimen were 2 in. from each end of the beam, thus giving a variable length between supports for specimens of different length, but an overhang so short as to be negligible in the calculations. Instead of using the poise for weigh-

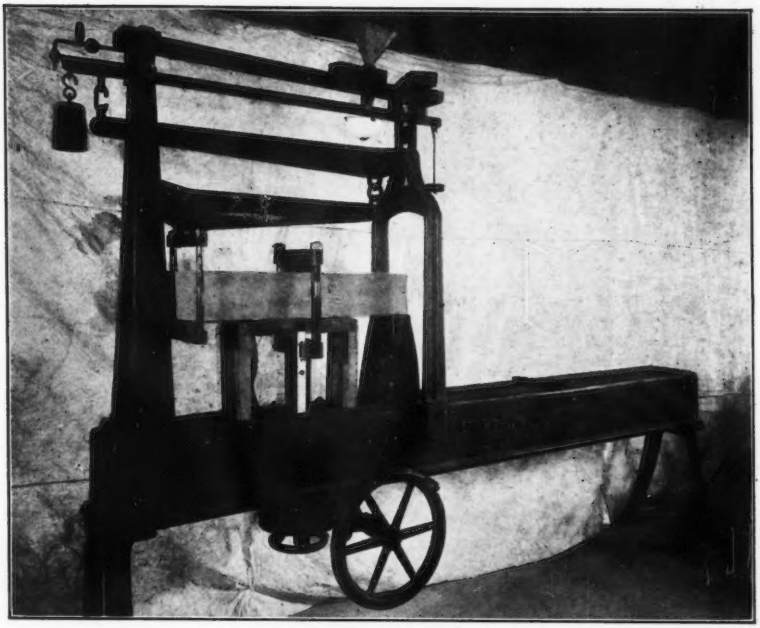


FIG. 1.—MACHINE FOR BREAKING BEAMS.

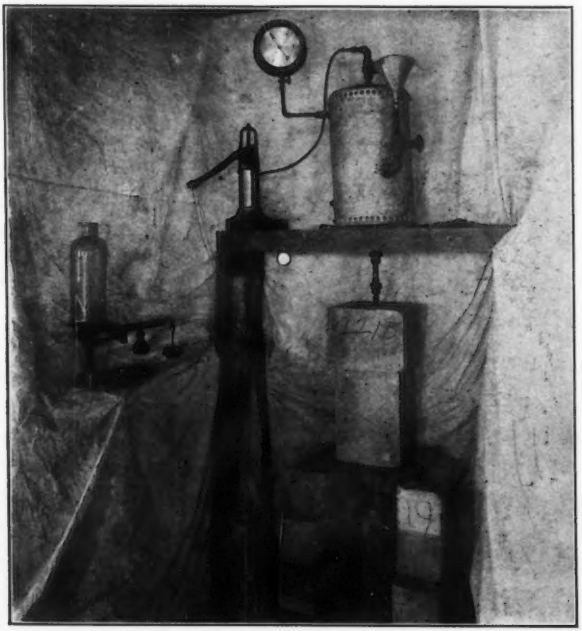
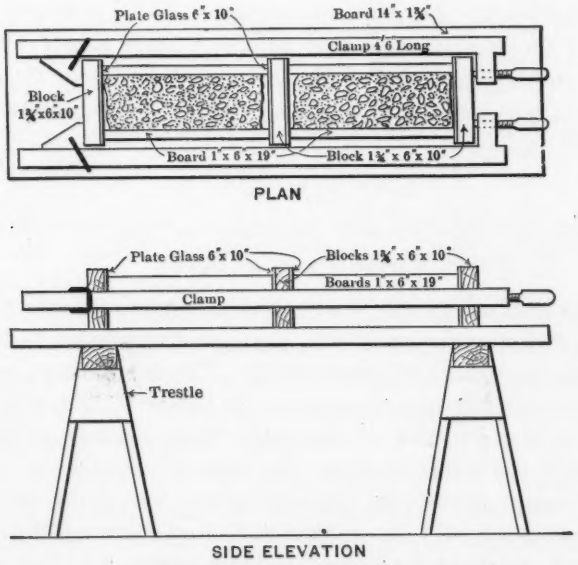


FIG 2.—APPARATUS FOR TESTING PERMEABILITY OF CONCRETE.

ing the load upon the beam, an attachment was designed, as shown in the top of the photograph, so that the beam was loaded by dropping shot from a tin funnel into a vessel suspended from the scale beam. This avoided the irregularities incident to the machine as furnished by the manufacturers.

Compression Tests.

As there is no constant relation between the transverse modulus of rupture of concrete and the compressive strength of the same



SKETCH SHOWING METHOD OF CAPPING TEST PRISMS FOR COMPRESSION.

Fig. 12.

mixture, a scheme was devised for obtaining the compressive strength of all of the mixtures, in addition to the transverse modulus of rupture. After breaking the beams into four pieces, the two end pieces were capped with neat cement so as to form prisms about 6 in. square and 19 in. long. The method of capping these prisms is illustrated in Fig. 12. Two pieces were capped by the same operation. A piece of smooth, planed, 2-in. plank was laid upon horses,

and upright upon this, in a wooden frame, were set four pieces of ¼-in. plate glass, each 6 by 10 in. The lengths of the prisms were gauged by boards, 1 by 6 by 19 in., placed lengthwise and 6 in. apart, so that the broken piece of the beam fitted between them with a space at each end between the rough ends of the beam and the plate glass. The pieces of beams were thoroughly soaked with water before beginning the operation. A plastic paste of neat cement, as stiff as could be readily handled and moulded, was next worked into the spaces between the ends of the specimen and the plate glass, and allowed to set over night. When removed from the mould, each prism was found capped with neat cement having a smooth, glossy surface, and the two ends were parallel. These prisms were sent to the Stevens Institute of Technology, at Hoboken, N. J., and broken in the compression machine. Certain ones were tested there for elasticity, also.

Comparative Comprehensive Strength of True Prisms *versus* Capped Pieces of Beams.

The question naturally arose as to whether the strength of prisms capped with neat cement in this way would correspond to the true compressive strength of the concrete. The neat cement capping, which was of different thickness in the different specimens, might affect the strength, and the specimens might be strained from the rupture in the transverse tests. In order to compare the strength of the capped pieces with the true prisms, one of the beam mixtures, consisting of 1 : 9 concrete with graded Jerome Park 2½-in. aggregate, was used for making up four prisms, 6 by 6 by 18 in., and these true prisms were broken at the same age as the capped pieces of beams mixed with the same ingredients and in like proportions. The results of this comparison are shown in Table 7. It is noticeable that the capped prisms gave a higher average strength than the true prisms, and that there is greater variation between the different specimens. The variation, however, is not great enough to affect the value of the results from the capped pieces, at least, when used in connection with the values of transverse strength. The full results of the compressive tests are given in Table 8.

TABLE 7.

True Prisms.			Capped Pieces of Beams.*		
Reference Numbers.	Compressive strength, in pounds per square inch.	Variations from mean.	Reference Numbers.	Compressive strength, in pounds per square inch.	Variations from mean.
161	1 375	93	155	1 580	153
161	1 240	42	155	1 450	23
161	1 235	47	155	1 250	177
162	1 330	48	157	1 490	63
162	1 315	33	157	1 485	58
162	1 195	87	157	1 305	122
Average.....	1 282	58	Average.....	1 427	99
Percentage...	.....	4.5	.....	.....	14.4

* The compression tests in the other tables are made upon the capped pieces of beams.

Results of Tests.

Table 8 contains a list of the 1905 beam tests, giving the composition, density, transverse strength, and compressive strength of the various mixtures.

Inspection of the quantity of water in the beams, Columns 13 and 20, shows that the smaller stone, that is, the ½-in., requires the most water in gauging, and the coarsest stone, the 2½-in., the least. The Cowe Bay gravel and sand require less water than the broken stone and screenings.

The total volume of voids per cubic foot, Column 24, gives merely the complements of the densities in Column 19. The voids in the cement, Column 22, are based upon the voids in the two neat beams given first in the table, it being assumed in the concrete specimens that the voids due to the cement are in the same ratio to the weight of the cement per cubic foot of concrete as the voids in an average neat beam are to the weight of cement in this neat beam.

In determining the average strength of each mixture, Column 29, all the breaks of the two beams, which are in duplicate, were averaged, that is, if one of a pair of beams had only two breaks, while the other had three, the five breaking strengths were added together, and divided by five, instead of assuming that the two breaks gave the average of one beam and the three breaks the average of the other. The method followed is considered more accurate than

the other, because a beam which can be broken only once or twice is possibly imperfect, and therefore this beam should not have quite so large a place in the average as the beam with three breaks.

The compressive strength of the concrete prisms made by capping two pieces of each beam are given at the right of each sheet of Table 8. These prisms were broken by Professor Frederick L. Pryor at the Stevens Institute, and although the heads of the machine were fixed, the ends of the specimen were sufficiently parallel to give good results, nearly all the pieces breaking in a manner normal to long prisms. The breaks, as is usual with such specimens, were more longitudinal than is the case with cubes, where two pyramids are generally formed with their bases against the heads of the machine.

In computing Table 8 the following data have been used:

Volumes, cubic feet per 100 lb. as mixed:

Cement, 1.00;
Jerome Park screenings (crusher run), 1.06;
Jerome Park stone (crusher run), 1.03;
Jerome Park screenings and stone vary with the mixture;
Cowe Bay sand (natural), 1.11;
Cowe Bay gravel, 0.97.

Specific gravities:

Cement, 3.10;
Jerome Park screenings vary with the size;
Jerome Park stone, 2.78;
Mixture of Jerome Park screenings and stone, 2.77;
Cowe Bay sand, 2.65;
Cowe Bay gravel, 2.65.

Weights per cubic foot, as mixed:

Cement, 1.00;
Jerome Park screenings (crusher run), 94.8;
Jerome Park stone, 97.0;
Mixture of Jerome Park screenings and stone varies with the mixture;
Cowe Bay sand (natural), 90.0;
Cowe Bay gravel, 102.7.

TABLE 8.—Complete List of 1905 Beam Tests, Giving Composition, Transverse Strength of Beams, and Compressive Strength of Prisms, of Con
Graded Aggregates, and Different Proportions of Giant Portland Cement.
Beams, 6 by 6 by 72 in. Spans, 68 and 32 in. Prisms, 6 by 6 by 18 in.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)
Reference numbers.	Proportions, by weight.	Number of equation of mechanical analysis curve. See Table 10.	Percentage of cement to total dry materials.	Kind of stone.	Kind of sand.	Maximum size of stone, in inches.	Uniformly graded above diameter, in inches.	Percentage finer than diameter in Column 8.	Curve below diameter in Column 8.	Weight, in Pounds, of Materials in 1 Cu. Ft. of Beam as Mixed.				Totals.			Calculated Volume, in Cubic Feet, of Material in 1 Cu. Ft. of Beam as Mixed.					Volume of Voids in 1 Cu. Ft.			Transverse Strength.		Pounds per square inch.			Compressive Strength.	
										Cement.	Aggregate.	Total dry mixed.	Water.	As mixed.	Minimum.	Maximum.	Cement.	Aggregate.	Total dry.	Water.	Total.	Cement.	Aggregate.	Total.	Age, in days.	Number of breaks.	Maximum.	Minimum.	Average.	Age.	
210	Neat.	.....	.....	.....	.....	.....	.....	.....	.....	104.5	00.0	104.5	29.6	134.1	112.9	133.1	0.541	0.000	0.541	0.475	1.016	0.459	0.000	0.459	89	3	1 177	929	919	....	....
199	"	.....	.....	.....	.....	.....	.....	.....	.....	100.5	00.0	100.5	30.4	130.9	108.5	130.4	0.520	0.000	0.520	0.487	1.007	0.480	0.000	0.480	91	3	768	744		....	....
144	1:9	(7)	10	J. P.	J. P.	2½	0.10	29.9	Parabola.	15.0	135.0	150.0	10.2	160.2	151.2	158.9	0.078	0.780	0.858	0.163	1.021	0.066	0.076	0.142	90	3	303	248	276	....	....
146	1:9	(8)	10	"	"	2¼	0.10	31.4	"	15.4	138.2	153.6	9.3	162.9	154.8	166.1	0.080	0.799	0.879	0.149	1.028	0.067	0.054	0.121	90	3	266	231	251	....	....
148	1:9	(2)	10	"	"	2½	0.20	35.8	Ellipse.	15.0	135.0	150.0	10.2	160.2	151.2	158.9	0.078	0.780	0.858	0.163	1.021	0.066	0.076	0.142	90	3	282	246	265	154	....
149	1:9	(5)	10	"	"	2½	0.20	36.9	"	14.9	133.7	148.6	9.9	158.5	149.8	158.0	0.077	0.772	0.849	0.159	1.008	0.065	0.086	0.151	91	2	278	253	269	....	....
155	1:9	(1)	10	"	"	2½	0.20	37.8	"	15.0	134.5	149.5	10.8	160.3	150.6	158.5	0.078	0.777	0.855	0.173	1.028	0.066	0.079	0.145	90	3	284	244	243	142	....
157	1:9	(1)	10	"	"	2½	0.20	37.8	"	14.9	134.0	148.9	10.0	158.9	150.1	158.1	0.077	0.775	0.852	0.160	1.012	0.065	0.083	0.148	90	3	258	199		142	....
150	1:9	(6)	10	"	"	2½	0.20	38.6	"	14.8	133.3	148.1	8.9	157.0	149.3	157.6	0.076	0.771	0.847	0.143	0.990	0.064	0.089	0.153	91	2	293	246	269	149	....
156	1:9	(3)	10	"	"	2½	0.20	39.4	"	14.6	131.2	145.8	9.6	155.4	147.0	156.3	0.075	0.757	0.832	0.153	0.985	0.064	0.104	0.168	90	3	282	248	247	142	....
158	1:9	(3)	10	"	"	2½	0.20	39.4	"	14.5	131.0	145.5	9.8	155.3	146.7	156.0	0.075	0.757	0.832	0.157	0.989	0.064	0.104	0.168	90	3	254	201		141	....
145	1:9	(7)	10	"	"	1	0.10	34.2	Parabola.	14.3	129.0	143.3	11.8	155.1	144.4	155.8	0.074	0.725	0.799	0.189	0.988	0.063	0.138	0.201	90	2	286	241	264	....	....
147	1:9	(8)	10	"	"	1	0.10	35.0	"	14.4	130.1	144.5	9.9	154.4	145.7	155.2	0.075	0.753	0.828	0.159	0.987	0.064	0.108	0.172	90	2	226	222	224	....	....
151	1:9	(1)	10	"	"	1	0.10	35.9	Ellipse.	14.3	129.0	143.3	11.9	155.2	144.4	154.5	0.075	0.745	0.820	0.191	1.011	0.064	0.116	0.180	90	3	230	209	221	147	....
152	1:9	(1)	10	"	"	1	0.10	35.9	"	14.3	129.0	143.3	11.9	155.2	144.4	154.5	0.075	0.745	0.820	0.191	1.011	0.064	0.116	0.180	90	3	240	203		147	....
159	1:9	(3)	10	"	"	1	0.10	37.7	"	13.9	124.8	138.7	12.8	151.5	139.8	151.6	0.072	0.720	0.792	0.205	0.997	0.061	0.147	0.208	90	2	222	198	212	141	....
160	1:9	(3)	10	"	"	1	0.10	37.7	"	14.0	125.5	139.5	13.8	153.3	140.6	152.1	0.073	0.725	0.798	0.221	1.019	0.062	0.140	0.202	90	2	223	202		141	....
164	1:9	(1)	10	"	"	½	0.075	36.3	"	13.4	120.8	134.2	12.9	147.1	135.3	148.7	0.069	0.698	0.767	0.207	0.974	0.059	0.174	0.233	91	2	174	172	200	137	....
165	1:9	(1)	10	"	"	½	0.075	36.3	"	13.5	121.2	134.7	13.0	147.7	135.8	149.0	0.070	0.700	0.770	0.208	0.978	0.059	0.171	0.230	91	3	232	198		137	....
153	1:9	(2)	10	"	"	½	0.075	38.2	"	13.3	120.2	133.5	12.8	146.3	134.6	148.2	0.069	0.695	0.764	0.205	0.969	0.059	0.177	0.236	90	3	273	175	208	139	....
154	1:9	(2)	10	"	"	½	0.075	38.2	"	13.7	123.0	136.7	13.2	149.9	137.8	150.4	0.071	0.710	0.781	0.212	0.993	0.060	0.159	0.219	90	3	212	197		142	....
195	1:9	(3)	10	"	"	½	0.075	39.8	"	13.3	119.5	132.8	14.6	147.4	133.9	147.8	0.069	0.690	0.759	0.234	0.993	0.058	0.183	0.241	90	3	258	218	227	135	....
196	1:9	(3)	10	"	"	½	0.075	39.8	"	13.3	119.5	132.8	14.4	147.2	133.9	147.8	0.069	0.690	0.759	0.231	0.990	0.058	0.183	0.241	90	2	205	205		135	....
168	1: 2⅝: 6⅝	.....	10	"	"	2½	.....	.....	.....	14.6	131.3	145.9	9.6	155.5	147.1	156.3	0.076	0.758	0.834	0.154	0.988	0.064	0.102	0.166	90	3	207	76	205	135	....
169	1: 2⅝: 6⅝	.....	10	"	"	2½	.....	.....	.....	14.4	130.0	144.4	10.7	155.1	145.6	155.3	0.075	0.751	0.826	0.172	0.998	0.064	0.110	0.174	90	3	223	201		135	....
166	1: 3: 6	.....	10	"	"	2½	.....	.....	.....	14.2	127.7	141.9	8.9	150.8	143.0	153.7	0.074	0.737	0.811	0.143	0.954	0.063	0.126	0.189	91	3	311	225	247	137	....
167	1: 3: 6	.....	10	"	"	2½	.....	.....	.....	14.2	127.8	142.0	9.9	151.0	143.1	153.2	0.074	0.738	0.812	0.144	0.956	0.063	0.117	0.180	90	1	224	224		136	....
172	1: 2⅝: 6⅝	.....	10	"	"	1	.....	.....	.....	14.2	127.8	140.0	14.6	156.6	141.1	151.5	0.074	0.736	0.810	0.232	1.042	0.063	0.121	0.184	90	2	168	138	152	148	....
173	1: 2⅝: 6⅝	.....	10	"	"	1	.....	.....	.....	14.1	127.2	141.3	11.2	152.5	142.4	153.3	0.073	0.735	0.808	0.180	0.988	0.062	0.130	0.192	91	2	187	117		145	....
170	1: 3: 6	.....	10	"	"	1	.....	.....	.....	14.0	126.3	140.3	14.0	154.3	141.4	152.6	0.072	0.730	0.802	0.226	1.028	0.061	0.137	0.198	90	3	205	116	175	133	....
171	1: 3: 6	.....	10	"	"	1	.....	.....	.....	13.8	125.4	139.2	12.5	151.7	140.3	151.9	0.071	0.725	0.796	0.200	0.996	0.060	0.144	0.204	90	3	199	160		133	....
174	1: 3⅝: 5⅝	.....	10	"	"	1	.....	.....	.....	13.7	123.4	137.1	13.6	150.7	138.2	150.6	0.071	0.713	0.784	0.218	1.002	0.060	0.156	0.216	91	3	192	166	186	145	....
175	1: 3⅝: 5⅝	.....	10	"	"	1	.....	.....	.....	13.8	124.0	137.8	13.2	151.0	138.9	151.2	0.071	0.715	0.786	0.211	0.997	0.060	0.154	0.214	91	3	227	171		145	....
192	1: 2⅝: 6⅝	.....	10	"	"	½	.....	.....	.....	13.5	121.9	135.4	14.0	149.4	136.5	149.6	0.070	0.703	0.773	0.224	0.997	0.059	0.168	0.227	90	3	211	191	204	137	....
176	1: 3: 6	.....	10	"	"	½	.....	.....	.....	13.5	121.6	135.1	12.4	147.5	136.2	149.3	0.070	0.702	0.772	0.199	0.971	0.059	0.169	0.228	88	2	135	100	150	143	....
177	1: 3: 6	.....	10	"	"	½	.....	.....	.....	13.5	121.0	134.5	13.5	148.0	135.6	148.9	0.070	0.700	0.770	0.216	0.986	0.059	0.171	0.230	88	3	175	169		143	....
194	1: 3⅝: 5⅝	.....	10	"	"	½	.....	.....	.....	13.3	119.3	132.6	14.4	147.0	133.7	147.7	0.069	0.689	0.758	0.231	0.989	0.059	0.183	0.242	90	3	156	145	152	135	....
187	1: 9	(1a)	10	"	"	2¼	0.20	37.8	Ellipse.	14.9	134.0	148.9	9.6	158.5	150.1	158.1	0.077	0.775	0.852	0.154	1.006	0.065	0.083	0.148	90	2	269	244	257	141	....
188	1: 9	(3a)	10	"	"	1	0.10	37.7	"	13.9	125.6	139.5	12.8	152.3	140.6	152.2	0.072	0.725	0.797	0.205	1.002	0.061	0.142	0.203	90	2	230	228	229	141	....
198	1: 9	(3a)	10	"	"	½	0.075	39.8	"	13.4	121.0	134.4	14.3	148.7	135.5	148.8	0.069	0.700	0.769	0.229	0.998	0.059	0.172	0.231	91	2	181	179	180	145	....
178	1: 7	(2)	12½	"	"	2¼	0.20	35.8	"	18.5	129.6	148.1	9.1	157.2	149.6	157.8	0.096	0.748	0.844	0.146	0.990	0.081	0.075	0.156	88	3	268	208	245	....	....
179	1: 7	(1)	12½	"	"	2¼	0.20	37.8	"	18.7	130.8	149.5	11.8	161.3	151.0	158.7	0.097	0.755	0.852	0.189	1.041	0.082	0.066	0.148	92	2	293	135	223	....	....
180	1: 7	(1)	12½	"	"	2¼	0.20	37.8	"	18.1	127.5	145.6	11.3	156.9	147.0	156.1	0.094	0.737	0.831	0.181	1.012	0.079	0.090	0.169	92	3	235	223		....	....
181	1: 7	(3)	12½	"	"	2¼	0.20	39.4	"	18.4	128.8	147.2	9.7	156.9	148.7	157.3	0.095	0.743	0.838	0.155	0.993	0.081	0.081	0.162	91	3	334	282	272	....	....
182	1: 7	(3)	12½	"	"	2¼	0.20	39.4	"	18.1	127.0	145.1	10.8	155.9	146.5	155.8	0.094	0.735	0.829	0.173	1.002	0.079	0.092	0.171	92	3	292	188		....	....
191	1: 7	(4)	12½	"	"	2¼	0.20	41.3	"	17.5	122.8	140.3	11.2	151.5	141.7	152.8	0.091	0.709	0.800	0.180	0.980	0.077	0.123	0.200	91	2	289	262	276	....	....

NG COMPOSITION, TRANSVERSE STRENGTH OF BEAMS, AND COMPRESSIVE STRE
DED AGGREGATES, AND DIFFERENT PROPORTIONS OF GIANT PORTLAND CEM

Beams, 6 by 6 by 72 in. Spans, 68 and 32 in. Prisms, 6 by 6 by 18 in.

(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)
ameter in Column 8.	Weight, in Pounds, of Materials in 1 Cu. Ft. of Beam as Mixed.							Calculated Volume, in Cubic Feet, of Material in 1 Cu. Ft. of Beam as Mixed.					Volume of Voids in 1 Cu. Ft.		
	Cement.	Aggregate.	Total dry mixed.	Water.	Totals. As mixed.	Minimum.	Maximum.	Cement.	Aggregate.	Total dry.	Water.	Total.	Cement.	Aggregate.	Total.
.....	104.5	00.0	104.5	29.6	134.1	112.9	133.1	0.541	0.000	0.541	0.475	1.016	0.459	0.000	0.459
.....	100.5	00.0	100.5	30.4	130.9	108.5	130.4	0.520	0.000	0.520	0.487	1.007	0.480	0.000	0.480
abola.	15.0	135.0	150.0	10.2	160.2	151.2	158.9	0.078	0.780	0.858	0.163	1.021	0.066	0.076	0.142
"	15.4	138.2	153.6	9.3	162.9	154.8	166.1	0.080	0.799	0.879	0.149	1.028	0.067	0.054	0.121
lipse.	15.0	135.0	150.0	10.2	160.2	151.2	158.9	0.078	0.780	0.858	0.163	1.021	0.066	0.076	0.142
"	14.9	133.7	148.6	9.9	158.5	149.8	158.0	0.077	0.772	0.849	0.159	1.008	0.065	0.086	0.151
"	15.0	134.5	149.5	10.8	160.3	150.6	158.5	0.078	0.777	0.855	0.173	1.028	0.066	0.079	0.145
"	14.9	134.0	148.9	10.0	158.9	150.1	158.1	0.077	0.775	0.852	0.160	1.012	0.065	0.083	0.148
"	14.8	133.3	148.1	8.9	157.0	149.3	157.6	0.076	0.771	0.847	0.143	0.990	0.064	0.089	0.153
"	14.6	131.2	145.8	9.6	155.4	147.0	156.3	0.075	0.757	0.832	0.153	0.985	0.064	0.104	0.168
"	14.5	131.0	145.5	9.8	155.3	146.7	156.0	0.075	0.757	0.832	0.157	0.989	0.064	0.104	0.168
abola.	14.3	129.0	143.3	11.8	155.1	144.4	155.8	0.074	0.725	0.799	0.189	0.988	0.063	0.138	0.201
"	14.4	130.1	144.5	9.9	154.4	145.7	155.2	0.075	0.753	0.828	0.159	0.987	0.064	0.108	0.172
lipse.	14.3	129.0	143.3	11.9	155.2	144.4	154.5	0.075	0.745	0.820	0.191	1.011	0.064	0.116	0.180
"	14.3	129.0	143.3	11.9	155.2	144.4	154.5	0.075	0.745	0.820	0.191	1.011	0.064	0.116	0.180
"	13.9	124.8	138.7	12.8	151.5	139.8	151.6	0.072	0.720	0.792	0.205	0.997	0.061	0.147	0.208
"	14.0	125.5	139.5	13.8	153.3	140.6	152.1	0.073	0.725	0.798	0.221	1.019	0.062	0.140	0.202
"	13.4	120.8	134.2	12.9	147.1	135.3	148.7	0.069	0.698	0.767	0.207	0.974	0.059	0.174	0.233
"	13.5	121.2	134.7	13.0	147.7	135.8	149.0	0.070	0.700	0.770	0.208	0.978	0.059	0.171	0.230
"	13.3	120.2	133.5	12.8	146.3	134.6	148.2	0.069	0.695	0.764	0.205	0.969	0.059	0.177	0.236
"	13.7	123.0	136.7	13.2	149.9	137.8	150.4	0.071	0.710	0.781	0.212	0.993	0.060	0.159	0.219
"	13.3	119.5	132.8	14.6	147.4	133.9	147.8	0.069	0.690	0.759	0.234	0.993	0.058	0.183	0.241
"	13.3	119.5	132.8	14.4	147.2	133.9	147.8	0.069	0.690	0.759	0.231	0.990	0.058	0.183	0.241
.....	14.6	131.3	145.9	9.6	155.5	147.1	156.3	0.076	0.758	0.834	0.154	0.988	0.064	0.102	0.166
.....	14.4	130.0	144.4	10.7	155.1	145.6	155.3	0.075	0.751	0.826	0.172	0.998	0.064	0.110	0.174
.....	14.2	127.7	141.9	8.9	150.8	143.0	153.7	0.074	0.737	0.811	0.143	0.954	0.063	0.126	0.189
.....	14.2	127.8	142.0	9.9	151.0	143.1	153.2	0.074	0.738	0.812	0.144	0.956	0.063	0.117	0.180
.....	14.2	127.8	140.0	14.6	156.6	141.1	151.5	0.074	0.736	0.810	0.232	1.042	0.063	0.121	0.184
.....	14.1	127.2	141.3	11.2	152.5	142.4	153.3	0.073	0.735	0.808	0.180	0.988	0.062	0 130	0.192
.....	14.0	126.3	140.3	14.0	154.3	141.4	152.6	0.072	0.730	0.802	0.226	1.028	0.061	0.137	0.198
.....	13.8	125.4	139.2	12.5	151.7	140.3	151.9	0.071	0.725	0.796	0.200	0.996	0.060	0.144	0.204
.....	13.7	123.4	137.1	13.6	150.7	138.2	150.6	0.071	0.713	0.784	0.218	1.002	0.060	0.156	0.216
.....	13.8	124.0	137.8	13.2	151.0	138.9	151.2	0.071	0.715	0.786	0.211	0.997	0.060	0.154	0.214
.....	13.5	121.9	135.4	14.0	149.4	136.5	149.6	0.070	0.703	0.773	0.224	0.997	0.059	0.168	0.227
.....	13.5	121.6	135.1	12.4	147.5	136.2	149.3	0.070	0.702	0.772	0.199	0.971	0.059	0.169	0.228
.....	13.5	121.0	134.5	13.5	148.0	135.6	148.9	0.070	0.700	0.770	0.216	0.986	0.059	0.171	0.230
.....	13.3	119.3	132.6	14.4	147.0	133.7	147.7	0.069	0.689	0.758	0.231	0.989	0.059	0.183	0.242
lipse.	14.9	134.0	148.9	9.6	158.5	150.1	158.1	0.077	0.775	0.852	0.154	1.006	0.065	0.083	0.148
"	13.9	125.6	139.5	12.8	152.3	140.6	152.2	0.072	0.725	0.797	0.205	1.002	0.061	0.142	0.203
"	13.4	121.0	134.4	14.3	148.7	135.5	148.8	0.069	0.700	0.769	0.229	0.998	0.059	0.172	0.231
"	18.5	129.6	148.1	9.1	157.2	149.6	157.8	0.096	0.748	0.844	0.146	0.990	0.081	0.075	0.156
"	18.7	130.8	149.5	11.8	161.3	151.0	158.7	0.097	0.755	0.852	0.189	1.041	0.082	0.066	0.148
"	18.1	127.5	145.6	11.3	156.9	147.0	156.1	0.094	0.737	0.831	0.181	1.012	0.079	0.090	0.169
"	18.4	128.8	147.2	9.7	156.9	148.7	157.3	0.095	0.743	0.838	0.155	0.993	0.081	0.081	0.162
"	18.1	127.0	145.1	10.8	155.9	146.5	155.8	0.094	0.735	0.829	0.173	1.002	0.079	0.092	0.171
"	17.5	122.8	140.3	11.2	151.5	141.7	152.8	0.091	0.709	0.800	0.180	0.980	0.077	0.123	0.200

ESSIVE STRENGTH OF PRISMS, OF CONCRETE MADE WITH DIFFERENT
RTLAND CEMENT.
by 18 in.

(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)
Volume of Voids in 1 Cu. Ft.			Transverse Strength.					Compressive Strength.						
Cement.	Aggregate.	Total.	Age, in days.	Number of breaks.	Pounds per square inch. Maximum.	Minimum.	Average.	Age.	Number of breaks.	Pounds per square inch. Maximum.	Minimum.	Average.	Reference numbers.	Remarks.
.459	0.000	0.459	89	3	1 177	929	919	....	....	.....	.....	.....	210	.....
.480	0.000	0.480	91	3	768	744		....	....	.....	.....	.....	199	.....
.066	0.076	0.142	90	3	303	248	276	....	....	.....	.....	.....	144	Surface rocky.
.067	0.054	0.121	90	3	266	231	251	....	....	.....	.....	.....	146	Excess of fine sand.
.066	0.076	0.142	90	3	282	246	265	154	1	1 310	1 310	1 310	148	Surface rocky.
.065	0.086	0.151	91	2	278	253	269	....	....	.....	.....	.....	149	Very rocky.
.066	0.079	0.145	90	3	284	244	243	142	3	1 580	1 250	1 425	155	Surface rocky.
.065	0.083	0.148	90	3	258	199		142	3	1 490	1 305	1 425	157	"
.064	0.089	0.153	91	2	293	246	269	149	1	1 405	1 405	1 405	150	"
.064	0.104	0.168	90	3	282	248	247	142	2	1 325	1 235	1 280	156	"
.064	0.104	0.168	90	3	254	201		141	2	1 225	1 185	1 205	158	"
.063	0.138	0.201	90	2	286	241	264	....	....	.....	.....	.....	145	.....
.064	0.108	0.172	90	2	226	222	224	....	....	.....	.....	.....	147	.....
.064	0.116	0.180	90	3	230	209	221	147	2	1 155	1 015	1 085	151	.....
.064	0.116	0.180	90	3	240	203		147	2	1 060	980	1 020	152	.....
.061	0.147	0.208	90	2	222	198	212	141	2	920	795	855	159	Surface rocky.
.062	0.140	0.202	90	2	223	202		141	2	895	785	840	160	"
.059	0.174	0.233	91	2	174	172	200	137	2	835	770	800	164	"
.059	0.171	0.230	91	3	232	198		137	2	965	955	960	165	"
.059	0.177	0.236	90	3	273	175	208	139	2	895	850	870	153	.....
.060	0.159	0.219	90	3	212	197		142	2	890	870	880	154	.....
.058	0.183	0.241	90	3	258	218	227	135	2	1 025	1 005	1 015	195	.....
.058	0.183	0.241	90	2	205	205		135	2	1 015	910	965	196	.....
.064	0.102	0.166	90	3	207	76	205	135	2	930	785	860	168	.....
.064	0.110	0.174	90	3	223	201		135	2	920	900	910	169	.....
.063	0.126	0.189	91	3	311	225	247	137	2	1 210	1 060	1 135	166	.....
.063	0.117	0.180	90	1	224	224		136	2	1 065	965	1 015	167	.....
.063	0.121	0.184	90	2	168	138	152	148	2	875	855	865	172	.....
.062	0 130	0.192	91	2	187	117		145	2	965	740	855	173	.....
.061	0.137	0.198	90	3	205	116	175	133	2	920	860	890	170	.....
.060	0.144	0.204	90	3	199	160		133	2	855	845	850	171	.....
.060	0.156	0.216	91	3	192	166	186	145	2	890	795	845	174	.....
.060	0.154	0.214	91	3	227	171		145	2	980	875	930	175	.....
.059	0.168	0.227	90	3	211	191	204	137	2	1 105	875	990	192	Slightly rocky.
.059	0.169	0.228	88	2	135	100	150	143	2	690	670	680	176	.....
.059	0.171	0.230	88	3	175	169		143	2	835	740	790	177	.....
.059	0.183	0.242	90	3	156	145	152	135	2	830	815	825	194	.....
.065	0.083	0.148	90	2	269	244	257	141	2	1 535	1 165	1 350	187	Slightly rocky.
.061	0.142	0.203	90	2	230	228	229	141	2	970	915	950	188	.....
.059	0.172	0.231	91	2	181	179	180	145	2	900	875	890	198	.....
.081	0.075	0.156	88	3	268	208	245	....	2	1 410	1 250	1 330	178	Surface rocky.
.082	0.066	0.148	92	2	293	135	223	....	1	1 710	1 710	1 710	179	"
.079	0.090	0.169	92	3	235	223		....	2	1 180	1 090	1 135	180	"
.081	0.081	0.162	91	3	334	282	272	....	2	1 495	1 410	1 455	181	.....
.079	0.092	0.171	92	3	292	188		....	2	1 440	1 315	1 375	182	Slightly rocky.
.077	0.123	0.200	91	2	289	262	276	....	2	1 565	1 450	1 505	191	"

TABLE 8 (*Continued*).—COMPLETE LIST OF 1905 BEAM TESTS, GIVING COMPOSITION, TRANSVERSE STRENGTH OF BEAMS, AND COMPRESSIVE STRENGTH OF PRI
DIFFERENT GRADED AGGREGATES AND DIFFERENT PROPORTIONS OF GIANT PORTLAND CEMENT

Beams, 6 by 6 by 72 in. Spans, 68 and 32 in. Prisms, 6 by 6 by 18 in.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)
Reference numbers.	Proportions, by weight.	Number of equation of mechanical analysis curve. See Table 10.	Percentage of cement to total dry materials.	Kind of stone.	Kind of sand.	Maximum size of stone, in inches.	Uniformly graded above diameter, in inches.	Percentage finer than diameter in Column 8.	Curve below diameter in Column 8.	Weight, in Pounds, of Material in 1 Cu. Ft. of Beam as Mixed.				Totals.			Calculated Volume, in Cubic Feet, of Material in 1 Cu. Ft. of Beam as Mixed.					Volume of Voids, in 1 Cu. Ft.			Transverse Strength.					Compr	
										Cement.	Aggregate.	Total dry mix.	Water.	As mixed.	Minimum.	Maximum.	Cement.	Aggregate.	Total dry.	Water.	Total.	Cement.	Aggregate.	Total.	Age, in days.	Number of breaks.	Pounds per square inch. Maximum.	Minimum.	Average.	Age.	Number of breaks.
183	1:5^{67}	(1)	15	J. P.	J. P.	2½	0.20	37.8	Ellipse.	21.8	123.6	145.4	11.6	157.0	147.1	155.1	0.130	0.715	0.845	0.186	1.031	0.110	0.045	0.155	91	3	361	281	329	....	
184	1:5^{67}	(1)	15	"	"	2½	0.20	37.8	"	22.0	125.0	147.0	10.9	157.9	148.8	155.6	0.139	0.722	0.861	0.175	1.036	0.118	0.021	0.139	91	2	346	301		....	
185	1:5^{67}	(3)	15	"	"	2½	0.20	39.4	"	21.8	123.4	145.2	11.3	156.5	146.9	156.1	0.113	0.713	0.826	0.181	1.007	0.096	0.078	0.174	90	3	331	300	302	....	
186	1:5^{67}	(3)	15	"	"	2½	0.20	39.4	"	21.7	122.9	144.6	11.4	156.0	146.3	155.0	0.124	0.710	0.834	0.183	1.017	0.105	0.061	0.166	90	3	305	270		....	
190	1:5^{67}	(4)	15	"	"	2½	0.20	41.3	"	21.8	126.5	148.3	11.5	159.8	150.0	156.0	0.116	0.760	0.876	0.184	1.060	0.098	0.026	0.124	91	3	374	365	369	....	
193	1:11^{5}	(1)	8	"	"	2½	0.20	37.8	"	11.6	133.5	145.1	10.6	155.7	146.0	155.6	0.060	0.771	0.831	0.170	1.001	0.051	0.118	0.169	90	2	221	188	204	....	
197	1:11^{5}	(3)	8	"	"	2½	0.20	39.4	"	11.6	133.0	144.6	11.4	156.0	145.5	155.4	0.060	0.767	0.827	0.183	1.010	0.051	0.122	0.173	91	3	186	158	171	....	
189	1:11^{5}	(4)	8	"	"	2½	0.20	41.3	"	11.5	132.5	144.0	11.8	155.8	144.9	154.9	0.060	0.766	0.826	0.189	1.015	0.051	0.123	0.174	90	3	223	139	184	....	
217	1:8^{43}	(9)	10.6	Cowe Bay.	Cowe Bay.	2½	0.20	32.1	"	15.2	128.0	143.2	8.3	151.5	144.4	152.2	0.079	0.776	0.855	0.133	0.988	0.067	0.073	0.145	90	3	250	238	230	....	
220	1:8^{43}	(9)	10.6	"	"	2½	0.20	32.1	"	15.9	133.7	149.6	9.5	159.1	150.9	157.0	0.082	0.810	0.892	0.152	1.044	0.069	0.039	0.108	91	3	244	176		....	
221	1:2^{81}: 5^{62}	.....	10.6	"	"	2½	.....	.....	.....	14.7	124.0	138.7	9.8	148.5	139.9	149.4	0.076	0.750	0.826	0.157	0.983	0.064	0.110	0.174	91	3	243	211	242	....	
222	1:2^{81}: 5^{62}	.....	10.6	"	"	2½	.....	.....	.....	14.7	124.0	138.7	9.9	148.6	139.9	149.4	0.076	0.750	0.826	0.159	0.985	0.064	0.110	0.174	91	3	265	228		....	
234	1:8^{43}	(10)	10.6	"	"	2½	0.20	37.8	Ellipse.	15.3	129.0	144.3	9.2	153.5	145.5	153.0	0.079	0.781	0.860	0.147	1.007	0.067	0.073	0.140	91	3	274	228	256	....	
223	1:8^{43}	(9)	10.6	"	"	1	0.10	31.2	"	14.9	126.0	140.9	9.8	150.7	142.1	150.9	0.077	0.764	0.841	0.157	0.998	0.065	0.094	0.159	91	3	250	218	258	....	
226	1:8^{43}	(9)	10.6	"	"	1	0.10	31.2	"	15.1	127.2	142.3	10.4	152.7	143.5	151.8	0.078	0.770	0.848	0.167	1.015	0.066	0.086	0.152	90	3	332	253		146	
227	1: 2^{81}: 5^{62}	.....	10.6	"	"	1	.....	.....	.....	14.8	124.8	139.6	10.8	150.4	140.8	150.1	0.077	0.755	0.832	0.173	1.005	0.065	0.103	0.168	89	3	298	258	248	147	
228	1: 2^{81}: 5^{62}	.....	10.6	"	"	1	.....	.....	.....	15.1	128.3	143.4	9.2	152.6	144.6	152.5	0.078	0.777	0.855	0.147	1.002	0.066	0.079	0.145	89	3	232	214		146	
235	1:8^{43}	(11)	10.6	"	"	1	0.10	37.7	Ellipse.	14.8	125.0	139.8	9.9	149.7	141.0	150.1	0.078	0.757	0.835	0.158	0.993	0.066	0.099	0.165	90	3	282	262	272	141	
259	1:8^{43}	(9)	10.6	"	"	½	0.075	33.2	"	14.7	124.0	138.7	10.3	149.0	139.9	150.5	0.076	0.751	0.827	0.165	0.992	0.064	0.109	0.173	91	3	225	199	216	133	
236	1: 2^{81}: 5^{62}	.....	10.6	"	"	½	.....	.....	.....	14.3	120.6	134.9	10.9	145.8	136.0	147.1	0.074	0.730	0.804	0.175	0.979	0.063	0.133	0.196	90	1	170	170	176	141	
237	1: 2^{81}: 5^{62}	.....	10.6	"	"	½	.....	.....	.....	14.7	123.8	138.5	9.6	148.1	139.7	149.4	0.076	0.749	0.825	0.154	0.979	0.064	0.111	0.175	90	1	182	182		141	
224	1:6^{51}	(9)	13½	"	"	2½	0.20	32.1	Ellipse.	19.3	126.4	145.7	9.3	155.0	147.2	154.1	0.100	0.765	0.865	0.149	1.014	0.084	0.050	0.135	90	3	326	272	323	146	
225	1:5^{30}	(9)	15.9	"	"	2½	0.20	32.1	"	23.0	121.8	144.8	9.2	154.0	146.6	153.1	0.129	0.738	0.867	0.147	1.014	0.109	0.024	0.133	90	3	352	316		146	
233	1:10^{76}	(9)	8.5	"	"	2½	0.20	32.1	"	12.4	133.2	145.6	9.6	155.2	146.6	153.6	0.064	0.807	0.871	0.154	1.025	0.054	0.075	0.129	91	2	176	150	163	143	
229	1:8^{43}	(9a)	10.6	"	"	2½	0.20	32.1	"	15.8	133.6	149.4	9.2	158.6	150.7	156.1	0.082	0.810	0.892	0.147	1.039	0.069	0.039	0.108	92	2	263	226	252	143	
230	1:8^{43}	(9a)	10.6	"	"	2½	0.20	32.1	"	15.7	132.7	148.4	8.6	157.0	149.7	155.6	0.081	0.803	0.884	0.138	1.022	0.069	0.047	0.116	92	3	298	198		143	
231	1:8^{43}	(9a)	10.6	"	"	1	0.10	31.2	"	15.1	127.0	142.1	9.3	151.4	143.3	151.5	0.078	0.769	0.847	0.149	0.996	0.066	0.087	0.153	92	3	261	240	243	143	
232	1:8^{43}	(9a)	10.6	"	"	1	0.10	31.2	"	15.2	128.2	143.4	10.1	153.5	144.6	152.3	0.079	0.777	0.856	0.162	1.018	0.067	0.077	0.144	91	1	213	213		142	
200	1:8^{80}	(14)	10.2	J. P.	"	2½	0.20	31.2	"	14.6	128.3	142.9	10.2	153.1	144.1	153.7	0.076	0.750	0.826	0.164	0.990	0.064	0.010	0.174	91	3	270	242	256	141	
209	1:8^{80}	(15)	10.2	"	"	2½	0.20	33.0	"	15.3	135.0	150.3	10.0	160.3	151.5	158.5	0.079	0.790	0.869	0.160	1.029	0.067	0.064	0.131	90	3	310	280	298	139	
213	1:8^{80}	(12)	10.2	"	"	2½	0.20	33.8	"	15.4	135.9	151.3	9.5	160.8	152.5	159.2	0.080	0.793	0.873	0.152	1.025	0.068	0.059	0.127	91	3	284	270	289	136	
214	1:8^{80}	(12)	10.2	"	"	2½	0.20	33.8	"	15.4	136.0	145.9	9.9	155.8	147.1	153.7	0.080	0.795	0.875	0.159	1.034	0.068	0.057	0.125	91	3	331	274		136	
205	1: 2^{92}: 5^{88}	.....	10.2	"	"	2½	.....	.....	.....	14.7	129.1	143.8	10.1	153.9	144.9	154.3	0.076	0.755	0.831	0.162	0.993	0.064	0.105	0.169	90	1	210	210	172	142	
206	1: 2^{92}: 5^{88}	.....	10.2	"	"	2½	.....	.....	.....	14.8	130.0	144.8	10.5	155.3	146.0	155.0	0.077	0.760	0.837	6.168	1.005	0.065	0.098	0.163	91	1	138	138		140	
219	1:8^{80}	(16)	10.2	"	"	2½	0.20	37.8	Ellipse.	15.0	132.0	147.0	10.0	157.0	148.2	156.4	0.078	0.772	0.850	0.160	1.010	0.066	0.084	0.150	90	3	295	276	285	135	
201	1:8^{80}	(13)	10.2	"	"	1	0.10	31.2	"	14.5	128.0	142.5	11.6	154.1	143.7	153.6	0.075	0.748	0.823	0.186	1.009	0.064	0.113	0.177	91	3	248	220	251	141	
202	1:8^{80}	(13)	10.2	"	"	1	0.10	31.2	"	14.5	127.8	142.3	10.8	153.1	143.5	153.5	0.075	0.745	0.820	0.173	0.993	0.064	0.116	0.180	91	3	290	246		142	
210	1:8^{80}	(15)	10.2	"	"	1	0.10	33.2	"	14.5	127.6	142.1	10.3	152.4	143.3	153.3	0.075	0.745	0.820	0.163	0.983	0.064	0.116	0.180	90	3	300	280	288	139	
203	1:2^{92}:5^{98}	.....	10.2	"	"	1	.....	.....	.....	14.5	127.5	142.0	9.7	151.7	143.2	153.2	0.075	0.745	0.820	0.156	0.976	0.064	0.116	0.180	90	3	298	234	276	141	
204	1:2^{92}:5^{98}	.....	10.2	"	"	1	.....	.....	.....	14.4	126.7	141.1	9.8	150.9	142.3	152.6	0.075	0.740	0.815	0.157	0.972	0.064	0.121	0.185	90	2	298	255		141	
215	1:8^{80}	(17)	10.2	"	"	1	0.10	37.7	Ellipse.	14.4	126.7	141.1	11.0	152.1	142.3	152.6	0.075	0.740	0.815	0.176	0.991	0.064	0.121	0.185	91	3	261	241	249	136	
211	1:8^{80}	(15)	10.2	"	"	½	0.075	34.4	"	13.9	122.3	136.2	12.8	149.0	137.3	149.5	0.072	0.715	0.787	0.205	0.992	0.061	0.152	0.213	90	1	196	196	205	139	
212	1:8^{80}	(15)	10.2	"	"	½	0.075	34.4	"	13.7	120.4	134.1	14.9	149.0	135.2	148.1	0.071	0.705	0.776	0.239	1.015	0.060	0.164	0.224	90	3	217	202		139	
207	1:2^{92}:5^{98}	.....	10.2	"	"	½	.....	.....	.....	13.8	121.3	134.1	12.4	147.5	135.2	147.6	0.073	0.710	0.783	0.199	0.982	0.062	0.155	0.217	91	3	222	210	212	140	
208	1:2^{92}:5^{98}	.....	10.2	"	"	½	.....	.....	.....	14.0	123.0	137.0	12.3	149.3	138.1	150.0	0.072	0.719	0.791	0.197	0.988	0.061	0.148	0.209	91	3	235	192		140	
218	1:6^{27}	(12)	12½	"	"	2½	0.20	33.8	Ellipse.	19.2	131.3	150.5	9.4	159.9	152.0	158.9	0.099	0.767	0.866	0.151	1.017	0.084	0.050	0.134	90	3	413	353	379	135	
216	1:5^{24}	(12)	15.3	"	"	2½	0.20	33.8	"	22.7	126.0	148.7	9.6	158.3	150.5	157.9	0.117	0.735	0.852	0.154	1.006	0.099	0.049	0.148	91	3	445	391	409	136	

ESTS, GIVING COMPOSITION, TRANSVERSE STRENGTH OF BEAMS, AND COMPRESSIVE S
GRADED AGGREGATES AND DIFFERENT PROPORTIONS OF GIANT PORTLAND CEMEN

Beams, 6 by 6 by 72 in. Spans, 68 and 32 in. Prisms, 6 by 6 by 18 in.

	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(2
	Weight, in Pounds, of Material in 1 Cu. Ft. of Beam as Mixed.							Calculated Volume, in Cubic Feet, of Material in 1 Cu. Ft. of Beam as Mixed.					Volume of Voids, in 1 Cu. Ft.			Transver		
					Totals.													
	Cement.	Aggregate.	Total dry mix.	Water.	As mixed.	Minimum.	Maximum.	Cement.	Aggregate.	Total dry.	Water.	Total.	Cement.	Aggregate.	Total.	Age, in days.	Number of breaks.	pe
	21.8	123.6	145.4	11.6	157.0	147.1	155.1	0.130	0.715	0.845	0.186	1.031	0.110	0.045	0.155	91	3	
	22.0	125.0	147.0	10.9	157.9	148.8	155.6	0.139	0.722	0.861	0.175	1.036	0.118	0.021	0.139	91	2	
	21.8	123.4	145.2	11.3	156.5	146.9	156.1	0.113	0.713	0.826	0.181	1.007	0.096	0.078	0.174	90	3	
	21.7	122.9	144.6	11.4	156.0	146.3	155.0	0.124	0.710	0.834	0.183	1.017	0.105	0.061	0.166	90	3	
	21.8	126.5	148.3	11.5	159.8	150.0	156.0	0.116	0.760	0.876	0.184	1.060	0.098	0.026	0.124	91	3	
	11.6	133.5	145.1	10.6	155.7	146.0	155.6	0.060	0.771	0.831	0.170	1.001	0.051	0.118	0.169	90	2	
	11.6	133.0	144.6	11.4	156.0	145.5	155.4	0.060	0.767	0.827	0.183	1.010	0.051	0.122	0.173	91	3	
	11.5	132.5	144.0	11.8	155.8	144.9	154.9	0.060	0.766	0.826	0.189	1.015	0.051	0.123	0.174	90	3	
	15.2	128.0	143.2	8.3	151.5	144.4	152.2	0.079	0.776	0.855	0.133	0.988	0.067	0.078	0.145	90	3	
	15.9	133.7	149.6	9.5	159.1	150.9	157.0	0.082	0.810	0.892	0.152	1.044	0.069	0.039	0.108	91	3	
...	14.7	124.0	138.7	9.8	148.5	139.9	149.4	0.076	0.750	0.826	0.157	0.983	0.064	0.110	0.174	91	3	
...	14.7	124.0	138.7	9.9	148.6	139.9	149.4	0.076	0.750	0.826	0.159	0.985	0.064	0.110	0.174	91	3	
	15.3	129.0	144.3	9.2	153.5	145.5	153.0	0.079	0.781	0.860	0.147	1.007	0.067	0.073	0.140	91	3	
	14.9	126.0	140.9	9.8	150.7	142.1	150.9	0.077	0.764	0.841	0.157	0.998	0.065	0.094	0.159	91	3	
	15.1	127.2	142.3	10.4	152.7	143.5	151.8	0.078	0.770	0.848	0.167	1.015	0.066	0.086	0.152	90	3	
...	14.8	124.8	139.6	10.8	150.4	140.8	150.1	0.077	0.755	0.832	0.173	1.005	0.065	0.103	0.168	89	3	
...	15.1	128.3	143.4	9.2	152.6	144.6	152.5	0.078	0.777	0.855	0.147	1.002	0.066	0.079	0.145	89	3	
	14.8	125.0	139.8	9.9	149.7	141.0	150.1	0.078	0.757	0.835	0.158	0.993	0.066	0.099	0.165	90	3	
	14.7	124.0	138.7	10.3	149.0	139.9	150.5	0.076	0.751	0.827	0.165	0.992	0.064	0.109	0.173	91	3	
...	14.3	120.6	134.9	10.9	145.8	136.0	147.1	0.074	0.730	0.804	0.175	0.979	0.063	0.133	0.196	90	1	
...	14.7	123.8	138.5	9.6	148.1	139.7	149.4	0.076	0.749	0.825	0.154	0.979	0.064	0.111	0.175	90	1	
	19.3	126.4	145.7	9.3	155.0	147.2	154.1	0.100	0.765	0.865	0.149	1.014	0.084	0.050	0.135	90	3	
	23.0	121.8	144.8	9.2	154.0	146.6	153.1	0.129	0.738	0.867	0.147	1.014	0.109	0.024	0.133	90	3	
	12.4	133.2	145.6	9.6	155.2	146.6	153.6	0.064	0.807	0.871	0.154	1.025	0.054	0.075	0.129	91	2	
	15.8	133.6	149.4	9.2	158.6	150.7	156.1	0.082	0.810	0.892	0.147	1.039	0.069	0.039	0.108	92	2	
	15.7	132.7	148.4	8.6	157.0	149.7	155.6	0.081	0.803	0.884	0.138	1.022	0.069	0.047	0.116	92	3	
	15.1	127.0	142.1	9.3	151.4	143.3	151.5	0.078	0.769	0.847	0.149	0.996	0.066	0.087	0.153	92	3	
	15.2	128.2	143.4	10.1	153.5	144.6	152.3	0.079	0.777	0.856	0.162	1.018	0.067	0.077	0.144	91	1	
	14.6	128.3	142.9	10.2	153.1	144.1	153.7	0.076	0.750	0.826	0.164	0.990	0.064	0.010	0.174	91	3	
	15.3	135.0	150.3	10.0	160.3	151.5	158.5	0.079	0.790	0.869	0.160	1.029	0.067	0.064	0.131	90	3	
	15.4	135.9	151.3	9.5	160.8	152.5	159.2	0.080	0.793	0.873	0.152	1.025	0.068	0.059	0.127	91	3	
	15.4	136.0	145.9	9.9	155.8	147.1	153.7	0.080	0.795	0.875	0.159	1.034	0.068	0.057	0.125	91	3	
...	14.7	129.1	143.8	10.1	153.9	144.9	154.3	0.076	0.755	0.831	0.162	0.993	0.064	0.105	0.169	90	1	
..	14.8	130.0	144.8	10.5	155.3	146.0	155.0	0.077	0.760	0.837	0.168	1.005	0.065	0.098	0.163	91	1	
.	15.0	132.0	147.0	10.0	157.0	148.2	156.4	0.078	0.772	0.850	0.160	1.010	0.066	0.084	0.150	90	3	
	14.5	128.0	142.5	11.6	154.1	143.7	153.6	0.075	0.748	0.823	0.186	1.009	0.064	0.113	0.177	91	3	
	14.5	127.8	142.3	10.8	153.1	143.5	153.5	0.075	0.745	0.820	0.173	0.993	0.064	0.116	0.180	91	3	
	14.5	127.6	142.1	10.3	152.4	143.3	153.3	0.075	0.745	0.820	0.163	0.983	0.064	0.116	0.180	90	3	
...	14.5	127.5	142.0	9.7	151.7	143.2	153.2	0.075	0.745	0.820	0.156	0.976	0.064	0.116	0.180	90	3	
...	14.4	126.7	141.1	9.8	150.9	142.3	152.6	0.075	0.740	0.815	0.157	0.972	0.064	0.121	0.185	90	2	
.	14.4	126.7	141.1	11.0	152.1	142.3	152.6	0.075	0.740	0.815	0.176	0.991	0.064	0.121	0.185	91	3	
	13.9	122.3	136.2	12.8	149.0	137.3	149.5	0.072	0.715	0.787	0.205	0.992	0.061	0.152	0.213	90	1	
	13.7	120.4	134.1	14.9	149.0	135.2	148.1	0.071	0.705	0.776	0.239	1.015	0.060	0.164	0.224	90	3	
...	13.8	121.3	134.1	12.4	147.5	135.2	147.6	0.073	0.710	0.783	0.199	0.982	0.062	0.155	0.217	91	3	
...	14.0	123.0	137.0	12.3	149.3	138.1	150.0	0.072	0.719	0.791	0.197	0.988	0.061	0.148	0.209	91	3	
.	19.2	131.3	150.5	9.4	159.9	152.0	158.9	0.099	0.767	0.866	0.151	1.017	0.084	0.050	0.134	90	3	
	22.7	126.0	148.7	9.6	158.3	150.5	157.9	0.117	0.735	0.852	0.154	1.006	0.099	0.049	0.148	91	3	

OMPRESSIVE STRENGTH OF PRISMS OF CONCRETE MADE WITH LAND CEMENT

(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)
	TRANSVERSE STRENGTH.					COMPRESSIVE STRENGTH.						
Total.	Age, in days.	Number of breaks.	Pounds per square inch. Maximum.	Minimum.	Average.	Age.	Number of breaks.	Pounds per square inch. Maximum.	Minimum.	Average.	Reference numbers.	Remarks.
0.155	91	3	361	281	329	....	2	1 920	1 745	1 830	183	.....
0.139	91	3	346	301		....	2	1 715	1 605	1 660	184	Surface rocky.
0.174	90	3	331	300	302	....	2	1 795	1 750	1 770	185	"
0.166	90	3	305	270		....	2	1 370	1 630	1 500	186	.....
0.124	91	3	374	365	369	....	2	1 425	1 395	1 410	190	.....
0.169	90	2	221	188	204	....	2	1 100	940	1 020	193	Slightly rocky.
0.173	91	3	186	158	171	....	2	965	915	940	197	"
0.174	90	3	223	139	184	....	2	970	970	970	189	.....
0.145	90	3	250	238	230	....	2	1 880	1 555	1 715	217	.....
0.108	91	3	244	176		....	2	1 440	1 260	1 350	220	.....
0.174	91	3	243	211	242	....	2	1 455	1 175	1 315	221	.....
0.174	91	3	265	228		....	2	1 485	1 310	1 395	222	.....
0.140	91	3	274	228	256	....	2	1 800	1 800	1 800	234	.....
0.159	91	3	250	218	258	....	2	1 445	1 145	1 295	223	.....
0.152	90	3	332	253		146	2	1 565	1 545	1 555	226	.....
0.168	89	3	298	258	248	147	2	2 065	1 660	1 860	227	.....
0.145	89	3	232	214		146	2	1 365	1 185	1 275	228	.....
0.165	90	3	282	262	272	141	2	1 590	1 535	1 580	235	.....
0.173	91	3	225	199	216	133	2	1 650	1 575	1 610	259	.....
0.196	90	1	170	170	176	141	2	1 265	1 025	1 145	236	.....
0.175	90	1	182	182		141	2	980	895	885	237	.....
0.135	90	3	326	272	323	146	2	2 110	1 670	1 890	224	.....
0.133	90	3	352	316		146	2	2 315	1 760	2 040	225	.....
0.129	91	2	176	150	163	143	2	1 045	940	990	233	.....
0.108	92	2	263	226	252	143	2	1 415	1 270	1 340	229	.....
0.116	92	3	298	198		143	2	1 790	1 170	1 480	230	.....
0.153	92	3	261	240	243	143	2	1 740	1 485	1 610	231	.....
0.144	91	1	213	213		142	2	1 205	980	1 090	232	.....
0.174	91	3	270	242	256	141	2	1 335	1 230	1 280	200	Surface rocky.
0.131	90	3	310	280	298	139	2	1 635	1 605	1 620	209	"
0.127	91	3	284	270	289	136	2	2 000	1 800	1 900	213	"
0.125	91	3	331	274		136	2	1 925	1 825	1 875	214	"
0.169	90	1	210	210	172	142	2	1 480	1 120	1 300	205	.....
0.163	91	1	138	138		140	2	1 435	1 265	1 350	206	.....
0.150	90	3	295	276	285	135	2	1 775	1 410	1 590	219	.....
0.177	91	3	248	220	251	141	2	1 375	1 265	1 320	201	Surface rocky.
0.180	91	3	290	246		142	2	1 565	1 550	1 560	202	"
0.180	90	3	300	280	288	139	2	1 875	1 660	1 770	210	.....
0.180	90	3	298	234	276	141	2	1 745	1 555	1 650	203	.....
0.185	90	2	298	255		141	2	1 520	1 435	1 475	204	.....
0.185	91	3	261	241	249	136	2	1 545	1 345	1 445	215	.....
0.213	90	1	196	196	205	139	2	1 175	1 085	1 130	211	.....
0.224	90	3	217	202		139	2	1 170	1 080	1 125	212	.....
0.217	91	3	222	210	212	140	2	1 385	1 235	1 310	207	.....
0.209	91	3	235	192		140	2	1 205	1 145	1 175	208	.....
0.134	90	3	413	353	379	135	2	2 230	2 150	2 190	218	Slightly rocky.
0.148	91	3	445	391	409	136	2	2 440	1 840	2 140	216	.....

Column 16 = Column 11 × 0.08 + Column 13.

Column 17 = Column 13 + (Column 25 × 62.4).

Column 16 represents the theoretical minimum, assuming 8% of water for chemical combination.

Column 17 represents the theoretical maximum, assuming the voids to be filled with water.

Comparative Tests of Density and Strength Forming the Basis of Conclusions.

In order to bring out more clearly the comparative relations of the beams tested which have warranted the conclusions stated at the beginning of this paper, short tables grouping the essential facts which form the basis of the conclusions are presented in the following pages.

Concrete with Aggregates of Different Maximum Size.

Conclusions 1 and 2.

In Table 9 are shown the averages of density and of breaking tests of concrete mixtures of cement and aggregates of different maximum size. The figures represent the averages of all specimens tested, according to each character of mixing, with the exception of four specimens omitted, where the exceptionally low strength is due to voids not being filled. In every case but one the mixture with 2½-in. stone for the maximum size is denser than that with 1-in. stone, and in every case but one the 1-in. is denser than the ½-in. The modulus of rupture and the compressive strength of the specimens with the three sizes of stone follow the same general order, the concrete with coarse stone being always stronger than the finer, except in one case where the 1-in. is 1% stronger than the 2½-in.

The general averages are calculated at the bottom of the table, and also the ratios of density and strength, based on the 2½-in. material as unity. Comparing these ratios with the ratios of strength with different percentages of cement, as given in Table 15, it appears that an additional amount of cement to the extent of about one-sixth part with the maximum aggregate 1 in., and one-third part with the maximum aggregate ½ in., will be required to produce a concrete equal in strength to a concrete having a maximum aggregate of 2½ in.

TABLE 9.—AGGREGATES OF DIFFERENT MAXIMUM SIZE. COMPARATIVE DENSITY AND STRENGTH.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Reference Numbers.			Proportion, by weight.	Material.		Character of mixture.	Average Density.			Average Modulus of Rupture at 90 Days, in Pounds per Square Inch.			Average Compressive Strength at 140 Days, in Pounds per Square Inch.		
2¼-in. stone.	1-in. stone.	½-in. stone.		Stone.	Sand.		2¼-in. stone.	1-in. stone.	½-in. stone.	2¼-in. stone.	1-in. stone.	½-in. stone.	2¼-in. stone.	1-in. stone.	½-in. stone.
144, 146, 148, 149, 150, 155, 156, 157, 158, 166, 167, 168, 169.	145, 147, 151, 152, 159, 160, 170, 171, 172, 173, 174, 175.	164, 165, 195, 196, 176, 177, 192, 194.	1:9	J. Park.	J. Park.	Ideal.	0.851	0.810	0.767	257	226	208	1 849	950	915
187.	188.	198.	1:9	"	"	Natural.	0.821	0.798	0.768	211	171	162	980	879	881
217, 220, 221, 222, 229, 230, 234.	223, 226, 228, 231, 232, 235.	236, 237, 239.	1:9	Cowe Bay.	Cowe Bay.	Uniform aggregate.	0.832	0.797	0.769	257	229	180	1 850	950	890
209, 213, 214.	208, 204, 210, 215.	207, 208, 211, 212.	1:9	J. Park.	Cowe Bay.	Various.	0.869	0.847	0.833	243	246	189	1 486	1 402	1 291
						"	0.872	0.818	0.794	291	273	207	1 798	1 585	1 185
	Averages.....						0.847	0.814	0.788	252	229	189	1 891	1 153	1 008
	Ratios.....						1.00	0.96	0.93	1.00	0.91	0.75	1.00	0.88	0.72

CONCRETE WITH JEROME PARK *vs.* COWE BAY *vs.* MIXED AGGREGATES. Conclusions 3, 4 and 5.

Tables 10 and 11 give the comparative density and strength of concrete made with Jerome Park stone and screenings *vs.* Cowe Bay gravel and sand *vs.* Jerome Park stone and Cowe Bay sand. The proportions given are 1 : 9 and 1 : 3 : 6 by weight. This is not strictly true, because, in order to make a true comparison of the different materials, a correction was made for the Cowe Bay mixtures. Actually, the proportions for the straight Cowe Bay materials are 1 ; 8.43, and 1 : 2.81 : 5.62, and the actual proportions by weight for the mixed materials are 1 : 8.80 and 1 : 2.92 : 5.88. By making this correction, the proportions by absolute volume are exactly the same, and, as it is this which affects the composition, it is the proper method of proportioning in comparative tests. The results, accordingly, show the true relation between the rounded gravel and the broken stone.

The values in Table 10 are the results of tests of concrete composed of the aggregates and 10%, by weight, of cement graded to the best elliptical curve for each material, which represents in general the best possible mixture of each material with the given percentage of cement. In general, the straight Cowe Bay material produces the greatest density. This is undoubtedly due to the rounded character of the grains, and is in accord with the results of other experimenters. The mixed Jerome Park stone and Cowe Bay sand forms a concrete less dense than the straight Cowe Bay material, but denser than the straight Jerome Park; in other words, it is intermediate between the two.

The breaking strength does not follow the same direction as the density. The most noticeable difference is between the straight Cowe Bay and the mixed Jerome Park stone and Cowe Bay sand. The straight Cowe Bay material, although producing a denser mixture, is not so strong as the mixed material in two cases out of three, even although, as shown in Column 18 of Table 8, the amount of cement in a cubic foot of the Cowe Bay concrete is greater than in a like volume of the other. An examination of the tests indicates that the one test with ½-in. stone which does not follow this rule is the erratic one rather than the other two, since in the transverse tests the difference in the ½-in. specimens

TABLE 10.—JEROME PARK *vs.* COWE BAY *vs.* MIXED AGGREGATES, EACH GRADED TO THE BEST ELLIPTICAL CURVE FOR THAT MATERIAL. COMPARATIVE DENSITY AND STRENGTH.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Reference numbers.	Proportion, by weight.	Maximum size of stone, in inches.	Density.			Modulus of Rupture at 90 Days, in Pounds per Square Inch.			Compressive Strength at 140 Days, in Pounds per Square Inch.		
			J. Park stone and screenings.	C. Bay gravel and sand.	J. Park stone. C. Bay sand.	J. Park stone and screenings.	C. Bay gravel and sand.	J. Park stone. C. Bay sand.	J. Park stone and screenings.	C. Bay gravel and sand.	J. Park stone. C. Bay sand.
155, 157; 217, 220; 218, 214.....	1 : 9	2½	0.854	0.874	0.874	248	230	230	1 425	1 533	1 898
151, 162; 223, 226; 210.....	1 : 9	1	0.830	0.845	0.830	221	258	288	1 052	1 425	1 770
164, 165; 259; 211, 212.....	1 : 9	¾	0.769	0.827	0.767	200	216	212	880	1 610	1 243
Averages.....	.....	.....	0.814	0.849	0.827	221	235	269	1 119	1 523	1 634

NOTE.—Weights of Cowe Bay material are corrected for difference in specific gravity, so as to have the same relative absolute volumes as the Jerome Park material.
See Table 5 for formulas.

is only 2%, whereas the difference in the tests of larger (2½-in. and 1-in.) stone is much greater, while in the compressive tests the strength of the ½-in. specimens, which averages 1 610 lb., appears abnormally large, being, in fact, greater than the tests above it with the coarser stone. It would appear from this that broken stone concrete of mica schist rock is stronger than gravel concrete under like conditions, and that this increase in strength is due to the difference in the surface of the coarse particles of stone. This, in general, is in accordance with the results of the best experiments, notably those of E. Candlot, in France, although it has been disputed in many quarters.

In Table 11 the mixtures of the different materials are in the same proportions (corrected for different specific gravity), and are not those demanded by the best analyses for each material. The results, therefore, are not apt to be so conclusive as those scheduled in Table 10, but it will be seen that they follow in general the same direction. The straight Cowe Bay gravel and sand mixture, while considerably denser than the mixed Jerome Park stone and Cowe Bay sand, is generally of lower strength than the latter. Tables 10 and 11 both indicate that a mixture of Jerome Park stone and screenings gives a concrete of lower density and lower strength than either the straight Cowe Bay mixtures or the mixed Jerome Park stone and Cowe Bay sand. In the 1 : 3 : 6 mixtures, Table 11, this might be due in part to the fact that the materials are not graded to the proportions which are best for them, but this difference is eliminated in Table 10. Further tests are essential to determine whether the principles just stated apply to other classes of broken stone. The age of the specimens also tends to affect the relative strength, because, if the mixture is rich enough, as the concrete becomes older there is more and more tendency in compressive tests for the stones to shear, so that the actual strength of the particles of stone become more and more a function of the strength of the concrete.

The results from these experiments, which indicate that sand with rounded grains produces a stronger concrete than broken-stone screenings in the same proportions, are apparently contradictory to certain tests by other experimenters. These other results may probably be accounted for either by the difference in the relative

TABLE 11.—JEROME PARK *vs.* COWE BAY *vs.* MIXED AGGREGATES, IN PROPORTIONS 1:3:6 BY WEIGHT. COMPARATIVE DENSITY AND STRENGTH.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Reference numbers.	Proportion, by weight.	Maximum size of stone, in inches.	Density.			Modulus of Rupture at 90 Days, in Pounds per Square Inch.			Compressive Strength at 90 Days, in Pounds per Square Inch.		
			J. Park stone and screenings.	C. Bay gravel and sand.	J. Park stone, C. Bay sand.	J. Park stone and screenings.	C. Bay gravel and sand.	J. Park stone, C. Bay sand.	J. Park stone and screenings.	C. Bay gravel and sand.	J. Park stone, C. Bay sand.
166, 167; 221, 222; 205, 206....	1:3:6	2½	0.812	0.896	0.894	247	242	174*	1 075	1 355	1 325
170, 171; 227, 228; 208, 304....	1:3:6	1	0.799	0.844	0.818	175	248	276	870	1 567	1 569
176, 177; 296, 297; 207, 308....	1:3:6	¼	0.771	0.815	0.787	150	176	219	735	1 015	1 242
Average.....	.....	.....	0.794	0.898	0.813	191	222	221	893	1 313	1 376

NOTE.—Weights of Cowe Bay material are corrected for difference in specific gravity, so as to have the same relative absolute volumes as the Jerome Park material.
*Only two breaks.

sizes of the sand and the screenings, or else by the possibility that in some cases the chemical composition of the screenings is such that the fine particles form a chemical combination with the cement.

Concrete with Aggregate Graded by Ideal Mechanical Analysis Curves *vs.* Mixtures of Natural Materials in Ordinary Proportions.

Conclusion 6.

Table 12 compares the density and strength of concrete graded by ideal mechanical analysis curves with the density and strength of natural proportions. The tests of graded mixtures in nearly every case are higher than the natural proportions. Greater differences would have appeared if the best ideal and best natural proportions had been selected instead of averaging all of them.

Instead of using the average of all the specimens made by artificial curves and the natural proportions, if a selection had been made of the specimens proportioned by the best ideal analysis curve with 2½-in. maximum stone—that is, by the lowest artificial curve with which the voids were filled, and by the best natural mixtures with the same size of stone, which, on the whole, were the 1 : 3 : 6 proportions—the average value of the modulus of rupture would have been 241 lb. per sq. in. for the ideal, and 211 lb. per sq. in. for the natural proportions, representing an increase in strength of 14% by using the ideal mixtures. The relative saving in cement is estimated with the aid of the data in Table 15.

Concrete with Aggregates Graded by Ideal Mechanical Analysis Curves Having Graded Coarse Aggregate *vs.* Aggregates Graded Similarly in the Sand Portion, but with Coarse Aggregate of Uniform Size.

Conclusion 7.

Trial mixtures of concrete made in the laboratory with uniform coarse stone gave greater density than could be obtained with uniformly graded stone. However, in the former, nearly 50% of the weight of total aggregate consisted of particles of the coarsest diam-

TABLE 12.—AGGREGATES GRADED BY IDEAL MECHANICAL ANALYSIS CURVES *vs.* MIXTURES OF NATURAL MATERIALS IN ORDINARY PROPORTIONS. COMPARATIVE DENSITY AND STRENGTH.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Reference number. Ideal mixtures.	Reference number. Natural mixtures.	Proportion, by weight.*	Materials.		Maximum size of stone, in inches.	Average Density.*		Average Modulus of Rupture at 90 Days, in Pounds per Square Inch.†		Average Compressive Strength at 140 Days, in Pounds per Square Inch.†	
			Stone.	Sand.		Ideal.	Natural.	Ideal.	Natural.	Ideal.	Natural.
144–146–148	166–167	1:9	J. Park.	J. Park.	2¼	0.851	0.821	257	211	1 342	980
149–150–155	168										
156–157–158	169										
145–147–151	170–171–172	1:9	"	"	1	0.810	0.798	226	171	950	873
152–159–160	173–174–175										
153–154–164	176–177	1:9	"	"	½	0.767	0.768	208	162	915	821
165–195–196	192–194										
217–220	221–222	1:9	Cowe Bay.	Cowe Bay.	2¼	0.863	0.826	230	242	1 535	1 355
223–226	227–228	1:9	"	"	1	0 845	0.844	258	249	1 425	1 505
259	236–237	1:9	"	"	½	0.827	0.817	216	176	1 610‡	1 040
200–209	.....	1:9	J. Park.	"	2¼	0.861	0.834	283	172‡	1 669	1 325
213–214	205–206										
210	203–204	1:9	"	"	1	0.820	0.818	288	276	1 770	1 565
211–212	207–208	1:9	"	"	½	0.782	0.787	202	212	1 125	1 240
Average....	... .	.....	.....	.....	.....	0.821	0.810	236	212	1 334	1 172

*In Cowe Bay mixtures the proportions are corrected for specific gravity so as to be the same by absolute volume.

†Average of all specimens tested by each character of mixture, except omitting 201, 202, 205 and 206, where an exceptionally low test is evidently due to voids not being filled.

‡Only two breaks.

eter of stone, and, in mixing, the concrete appeared to be very coarse, so that it was considered doubtful whether the concrete would work well in practice because of the apparent tendency of the mortar to run away from the stones, and leave pockets of stone and voids. Accordingly, in this 1905 series of experiments, only a few beams were made with the coarse stone of uniform size, in order to determine whether the results were sufficiently good to warrant the continuation of this line of tests at a future date, if circumstances permitted.

The results as indicated in Table 13 show no marked difference between the specimens with graded coarse stone and those with uniform coarse stone. The former average slightly higher in strength, while the latter have slightly greater density. This is contrary to what would be expected, since the tests in general indicate that the densest mixtures produce the strongest concrete. The fact can be explained at the present time only by assuming that the uniform coarse stone does tend to separate, as suggested above, and thus produces a less homogeneous concrete. Further tests are necessary, however, to determine whether this is true or whether these few results are abnormal. The analysis curves used in the mixtures of uniform stone are indicated in the diagrams. They were adopted as a result of the volumetric or density tests. The density tests indicated that a slightly better mixture would have been obtained by lowering the curve at the juncture of the ellipse and the first straight line, but since they also indicated that this style of curve required more very fine sand than a curve with graded coarse stone, it was thought best to adopt the curves shown, and then use, for comparison with them, the specimens with the graded stone, the analysis curve of which, in the sand portion, was the same ellipse.

Influence of the Analysis of the Coarse Aggregate upon the Strength of the Concrete.—One of the most important conclusions which may be drawn from the comparative tests shown in Table 13 is that there is comparatively little difference in the density and strength of concrete, whatever may be the analysis of the coarse aggregate (meaning by the "coarse aggregate" all the particles the sizes of which are greater than a diameter which is one-tenth the maximum diameter of the stone), provided this coarse aggregate

TABLE 13.—AGGREGATES GRADED BY IDEAL MECHANICAL ANALYSIS CURVES HAVING GRADED COARSE AGGREGATE *vs.* AGGREGATES GRADED SIMILARLY IN THE SAND PORTION, BUT WITH COARSE AGGREGATE OF UNIFORM SIZE. COMPARATIVE DENSITY AND STRENGTH.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Reference number. Graded stone.	Reference number. Uniform stone.	Proportion, by weight.	Materials.		Maximum size of stone, in inches.	Average Density.		Average Modulus of Rupture at 90 Days, in Pounds per Square Inch.		Average Compressive Strength at 140 Days, in Pounds per Square Inch.	
			Stone.	Sand.		Graded coarse stone.	Uniform coarse stone.	Graded coarse stone.	Uniform coarse stone.	Graded coarse stone.	Uniform coarse stone.
155, 157	187	1:9	J. Park.	J. Park.	2½	0.854	0.832	250	257	1 425	1 350
159, 160	188	1:9	"	"	1	0.795	0.797	212	229	848	950
195, 196	198	1:9	"	"	½	0.759	0.769	219	180	990	890
217, 220	229, 230	1:9	Cowe Bay	Cowe Bay.	2½	0.853	0.888	231	252	1 535	1 411
223, 226	231, 232	1:9	"	"	1	0.845	0.852	258	233	1 425	1 352
Average.						0.821	0.828	234	230	1 245	1 191

In Cowe Bay mixtures the proportions are corrected for specific gravity so as to be the same by absolute volume.

does not contain a greater weight of medium-sized particles than can be represented by a straight line. In other words, the coarse aggregate may be uniformly graded above the size corresponding to one-tenth the diameter of the coarsest particles, or it may contain an excess of uniform-sized stone the diameter of which is the same as the coarsest diameter of the graded stone. Expressed in another way, the effect upon the density and the strength is practically the same whether uniform stone or uniformly graded stone, or a mixture between these two, is used. However, tests should be made on a large scale, with concrete mixed by hand and by machine, before adopting uniform stone in regular construction work, in order to prove conclusively that the stones in the mixture of uniform stone do not separate from the mortar; in other words, that the concrete does not work harshly.

While the tests of strength do not include tests to determine whether or not it might be possible to use an excess of medium-sized stone over and above what would be contained in a uniformly-graded coarse aggregate, the tests of density indicate that when the curve of the coarse aggregate is raised above a straight line, the density is immediately decreased, signifying that the uniformly-graded coarse aggregate or an aggregate having a curve which is below a straight line, is the best to use.

Effect of Fineness of Sand upon Density and Strength.

Conclusions 8 and 9.

The relative effect of sand and stone upon the density and strength is evident from the preceding paragraphs. The density of the concrete is affected very much more by the variation in diameter of the sand particles than of the stone particles, an excess of fine or medium sand decreases both the density and strength of the concrete. The effect of the fineness of the sand, that is, the proportions of the different-sized grains, was carefully studied in the volumetric tests which have been described, and the results were confirmed by laboratory and field tests.

Relation of Ideal Curves of Different-Sized Stone.

From the preceding paragraphs it is evident that the equations of curves given on page 245 for aggregate plus cement show that, for

a given character of aggregate, a single equation in which the only variable is the diameter of the particles of maximum size will apply to aggregates having a maximum diameter varying from ½ in. to 2¼ in.

Effect of Density and Strength of Concrete by Increasing the Percentage of Sand and Decreasing the Percentage of Stone.

Conclusion 12.

The density experiments indicated very distinctly that, the best ideal curve of mechanical analysis having been found, raising this curve in any portion of its length decreases the density of the mixture. Accordingly, to test this point in the beam tests, as shown in the diagrams, Figs. 5 to 10, specimens were also made with each material proportioned according to a curve which was raised above the best ideal at the tangent point of the ellipse and straight line, the lower portion of these higher curves being still in the form of an ellipse with the same horizontal or major axis but with a longer minor axis. More simply expressed, this is equivalent to increasing the sand and decreasing the stone. It is evident from an examination of the full data in Table 8 that the results of this comparison were not as conclusive as might be desired. This is partly due to the slight difference between the various curves, to the comparatively few tests made with each curve, to the variation which must be expected in all tests of concrete, and to the fact that in some of the lowest curves the voids were not entirely filled and therefore the results are less accurate. With the natural mixtures, the same rather inconclusive results were obtained, the proportions selected being so nearly alike that the difference is not marked. The general trend of the tests, however, indicates that the theory assumed is correct, and it is certainly substantiated by previous tests, made by one of the writers at Little Falls, which indicate quite conclusively that, with the same proportions of cement to total aggregate, the strongest mixture is that with the largest possible proportion of stone and the smallest possible proportion of sand.

In Table 14 are given the results selected from these tests at Little Falls, N. J., made in 1901. All the specimens presented

have the same proportions by weight, namely 1 : 8. The ratio of sand to stone, however, is varied from 2 : 6 to 8 : 0. It is seen from an inspection of the table that in every case there is an increase in both density and strength as stone is substituted for an equal weight of sand.

TABLE 14.—EFFECT OF INCREASING THE PERCENTAGE OF SAND AND DECREASING THE STONE, FROM THE LITTLE FALLS EXPERIMENTS.

Proportion, by weight, of cement to total aggregate.		Absolute volume of cement.	Density, *i. e.* total cement + sand + stone.	Average modulus of rupture at 33 days, in pounds per square inch.
1:8	1:2:6	0.091	0.865	319
1:8	1:3:5	0.086	0.833	285
1:8	1:4:4	0.082	0.801	209
1:8	1:5:3	0.080	0.799	151
1:8	1:6:2	0.076	0.760	102
1:8	1:8:0	0.073	0.754	41

PROPORTIONING SAND AND STONE IN PRACTICE.

Conclusion 12.

Where two aggregates are used, such as natural sand and natural gravel, or crusher-run screenings and crusher-run broken stone, it is evident from the preceding paragraphs that the relative proportions of sand to stone may be properly graded in the field from day to day by using in all cases as little sand as possible, while avoiding visible voids in the concrete. In practice, when proportioned in this way, the mixture is found to be not only theoretically denser and stronger, but it works most smoothly in placing. Having selected a ratio of cement to total aggregate, this gives a better and easier method of proportioning in cases where it is not considered economical to use more than two aggregates—that is, where artificial grading is prohibited—than any number of theoretical tests. This plan is also especially advantageous where the sand varies in fineness from day to day; for, the finer the sand, the farther it will spread, and the less of it is required to fill the voids of the stone, and also the less of it should be used in proportion to the cement, since a mortar of fine sand is weaker than a mortar of coarse sand.

Concrete with Different Percentages of Cement.

Conclusion 10.

Table 15 shows the density and strength of beams in which different percentages of cement are used to the weight of the total dry material, ranging from 8 to 15%, and in proportions by weight from 1 : 11.5 to 1 : 5.7, thus covering all ordinary proportions in practice. As the percentage of cement is increased, the strength increases, and in nearly similar ratios.

Effect upon Density of Substituting Cement for Fine Sand.

Conclusions 10 and 11.

The average densities in Table 15 show an extreme variation of less than 1 per cent. This is in confirmation of the statement already made that a substitution of cement for fine sand having grains of the same diameter does not affect the density. This is also proved still more definitely in the volumetric tests of density. As the mechanical analysis curves in all the beam mixtures include both cement and aggregate, in the specimens with different percentages of cement the additional cement is actually substituted for sand having grains of the same size.

Permeability Tests.

The results of the permeability tests have emphasized the fact that little is known of the action of concrete in resisting the flow of water. Examination of the tests, which are given in full, in Table 18, indicates in general that, using different proportions and different sizes of the same class of materials, the laws of water-tightness are somewhat similar to those of strength. If the percentages of cement be the same, the specimens having the greatest density are usually most water-tight, and in the specimens having similar density but different percentages of cement, the water-tightness increases with the percentages of cement. The ratios, however, are very different from the ratios of either density or strength, a slight difference in the composition producing a great effect upon the water-tightness. Different kinds of aggregates, also, for reasons not yet explained, produce very different results in water-tightness. The results of the tests are discussed in detail

TABLE 15.—COMPARATIVE DENSITY AND STRENGTH OF SIMILAR CONCRETE WITH DIFFERENT PERCENTAGES OF CEMENT AND 2¼-INCH STONE GRADED AS AN ELLIPSE AND STRAIGHT LINE.

(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Reference numbers.	MATERIALS.		Uniformly graded above diameter, in.	Percentage finer than diameter in Column 3.	DENSITY WITH DIFFERENT PERCENTAGES OF CEMENT.*				MODULUS OF RUPTURE AT 90 DAYS, DIFFERENT PERCENTAGES OF CEMENT.*				COMPRESSIVE STRENGTH AT 14 DAYS, DIFFERENT PERCENTAGES OF CEMENT.			
	Stone.	Sand.			8%	10%	12½%	15%	8%	10%	12½%	15%	8%	10%	12½%	15%
193, 197, 198	J. Park.	J. Park.	0.20	37.8-39.4	0.829	.....	.....	.....	188	.....	.....	.....	980	.....	.....	.....
148, 155, 156	"	"	0.20	35.8, 37.8, 39.4	.....	0.846	.....	.....	.....	250	.....	.....	.....	1 129	.....	.....
157, 158	"	"	0.20	37.8-39.4												
178, 179, 180	"	"	0.20	35.8, 37.8, 37.8	.....	.....	0.832	.....	.....	.....	245	.....	.....	.....	1 418	.....
181, 182, 191	"	"	0.20	39.4, 39.4, 41.3												
183, 184	"	"	0.20	37.8, 37.8	.....	.....	.....	0.839	.....	.....	.....	326	.....	.....	.....	1 634
185, 186, 190	"	"	0.20	39.4, 39.4, 41.3												
233	C. Bay.	C. Bay.	0.20	32.1	0.871	.....	.....	.....	163	.....	.....	.....	990	.....	.....	.....
217	"	"	0.20	32.1	.....	0.855	.....	.....	.....	245	.....	.....	.....	1 715	.....	.....
224	"	"	0.20	32.1	.....	.....	0.865	.....	.....	.....	307	.....	.....	.....	1 890	.....
225	"	"	0.20	32.1	.....	.....	.....	0.867	.....	.....	.....	339	.....	.....	.....	2 040
Averages..	.....	.....	.....	....	0.850	0.850	0.848	0.853	176	248	276	332	985	1 428	1 654	1 837

*In Cowe Bay mixtures the percentage of cement by weight is increased in each case to balance the difference in specific gravity between this and the Jerome Park material.

on pages 287 to 292. An important result of the permeability tests has been the evolution of an apparatus, described in succeeding paragraphs, by which almost any character, shape or thickness of specimen may be submitted to water pressure. The advantages of the apparatus lie in the exposure of the entire top surface of the specimen to the water pressure, the coating of the sides of the specimen with neat cement so as to confine the flow, and the discharge of the water through the bottom of the specimen.

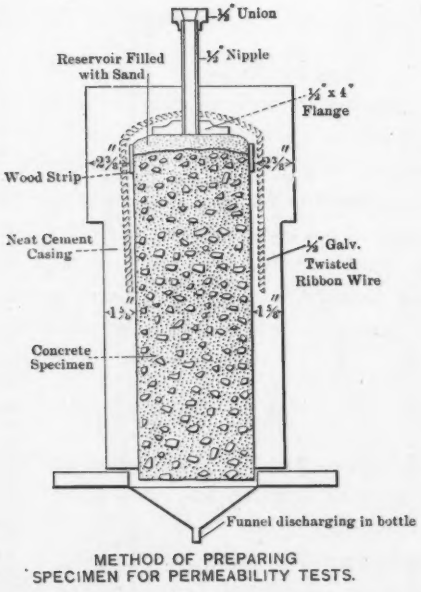


FIG. 13.

Method of Making Permeability Tests.—The apparatus used in making permeability tests and the preparation of the specimen are indicated in Fig. 13, and in Fig. 2, Plate XIII. The method of preparing the specimen which was found satisfactory after a number of trials is illustrated in Fig. 12. A piece of a concrete beam, about 6 in. square and 17 in. long, obtained by breaking the beam in the regular manner in the testing machine, is scored over the surface of its four sides by a hammer and cold chisel, so as to

give rough and uneven surfaces and afford a better adhesion to the cement coating. The specimen is then immersed in water and soaked for 24 hours. When taken from the water, it is placed in a wooden mould constructed so that the specimen can be placed in an upright position with a space on each of the four sides. A mound of sand is formed on the top and held in place by a strip of wood first thoroughly soaked with water. The surface of the sand is covered with a piece of tissue paper to prevent the cement from flowing into it. The requisite quantity of sand is 1 000 g., and it must be fine, passing a No. 30 and being caught on a No. 40 sieve. On top of the sand is placed a 4-in. iron flange in which a ½-in. nipple, 4½ in. long, is screwed so as to make a tight joint in which there can be no leakage along the thread.

Neat cement, mixed to a paste about as stiff as can be handled and compacted conveniently, is placed in the mould, around the specimen and over the sand, thus forming a dome above it. About 83 lb. of cement and 21 lb. of water are used for the casing. When pouring the cement, four pieces of ½-in. galvanized ribbon wire, or some other form of reinforcing metal, are placed in pairs, two at right angles to the other two, over the top of the specimen and down along the side, as shown in Fig. 13, to reinforce the cement and prevent the dome from being blown off, which occurred in one of the experimental tests. As the cement is compacted, water rises to the surface, and bubbles of air come up through the cement and water. The casing is not considered complete until this bubbling ceases. The surface of the specimen, after it is complete, is covered with moist sand, and this is kept wet by a very slow flow from a water cooler. At the end of 24 hours, the neat cement has thoroughly set, and the specimen can be removed from the mould and buried in damp sand until ready to test.

Apparatus for Testing Permeability. The apparatus for testing, together with the specimen itself, is shown in Fig. 2, Plate XIII. The specimen is placed upon a tin funnel set in a wooden frame which rests upon any suitable foundation. The pipe projecting through the top of the specimen is connected by a union coupling with the bottom of the air-pressure tank, which is nearly filled with water before beginning the test. The pressure is raised by the hand-pressure air pump shown in the photograph, and main-

tained at any desired pressure for any required period. The time is read by a stop-watch reading for convenience to hundredths of minutes, instead of to seconds, which is started at the beginning of the tests and allowed to run as long as the experiment is continued. The water is caught in a bottle placed below the funnel under the specimen, and weighed at intervals by substituting a second bottle.

Recording the Data.—The method of recording the data of the tests is shown in a typical form in Table 16. Convenient periods of flow for most of the specimens were found to be 5-min. intervals, this giving sufficient time to weigh the bottle, and being frequent enough to obtain the average rates of flow. It was found that about 5 min. were required for the flow at any given pressure to become constant, and therefore the flow during the first 5 min. at any given pressure is not included in computing the average flow.

TABLE 16.—FORM FOR PERMEABILITY TESTS.

Specimen No. 165.—Maximum Size of Stone, $\frac{1}{2}$ in.—Analysis No. *378.*—Normal Mix: *Ellipse, 37% ordinate at diam. .105, Tangent to 100%.*—Per Cent. of Cement, *10%*.—Kind Stone, *J. P.*—Kind of Sand, *J. P.*—Date Mixed, *Feb. 20.*—Date Beam Broken, *May 22.*—Age at Break, *91 d.*—Date of Coating, *May 23.*—Age at Perm. Test, *112 d.*—Dimensions before Coating, *5.91* × *5.95* × *18.0.**—Hours Soaked before Coating, *24.*—Time Valve Opened, *10.45.*

Times.	Pressure.	Water passing, in grammes.	Rate of flow per minute, in grammes.	Remarks.
0	20 lb.	0		
10	" "	0	0	Pressure increased to 40 lb.
25	40 "	0		" " 60 "
29	60 "			Water appeared.
35	60 "	61		
40	" "	98		
45	" "	103	20	
50	" "	99		
55	80 "	150		Pressure increased to 80 lb.
60	" "	177		
65	" "	189	36	
		168		

GENERAL REMARKS.

Water appeared after a pressure of 20 lb. had been applied for 10 min., of 40 lb. 15 min., and 60 lb. 4 min., making specimen under increasing pressures 29 min. before water appeared.

*This measurement is assumed to be 18 in. Other dimensions taken before surface was roughened.

Adhesion of Cement Casting to Concrete Block.—The only possibility of a leakage which is not immediately apparent is between

the specimen and the neat cement casing. In order to prove that the adhesion was perfect, several specimens were broken after the completion of the tests. One of the first specimens showed signs of slight percolation between the specimen and the coating, but by more carefully roughening the surface before coating, this was entirely prevented in subsequent tests, and the bond of union was found to be absolutely perfect, the adhesion of the cement casing to the concrete being stronger than the adhesion of the ingredients of the concrete.

Results of Permeability Tests.—An examination of Table 18 reveals a number of points, which stand out very clearly in the results, and form the basis for the conclusions on the following pages. To establish definite laws, and compare materials not included in this series of tests, further experiments are essential. The permeability of the different specimens is indicated in Columns 18 to 21 by the rate of flow, in grammes per minute, at different pressures. The specimens are all of approximately the same length, namely, 17 in., and the flow is through this total length.

TABLE 17.—EFFECT OF PERCENTAGE OF CEMENT ON PERMEABILITY OF CONCRETE BEAMS OF VARIOUS AGGREGATES HAVING A MAXIMUM DIAMETER OF 2¼ INCHES.

No. of Beam.	Proportion, by weight.	Percentage of cement to total dry material.	Kind of Material.		Time in which water appears, in minutes.	Rate of Flow of Water, in Grammes per Minute, at the Following Pressures, per Square Inch.			
			Stone.	Sand.		20 lb.	40 lb.	60 lb.	80 lb.
193	1:11.5	8.0	J. P.*	J. P.	7	25	161	237	273
155	1:9	10.0	"	"	3	11	24	369	49
179	1:7	12.5	"	"	3	15	22	30	38
183	1:5.75	15.0	"	"	5.5	5	8	10	12
233	1:10.8	8.5	C. B.	C. B.	3	15	25	38	43
217	1:8.4	10.6	"	"	17	1	3	5	6
224	1:6.5	13.0	"	"	100	0	0	0	0.5
225	1:5.3	15.9	"	"	98	0	0	0	1.4
213	1:8.8	10.2	J. P.	C. B.	9	4	11	17	22
218	1:6.88	12.7	"	"	10	2	2	3	3
216	1:5.54	15.6	"	"	.....	0	0	0.7	1.4

*J. P. = Jerome Park; C. B. = Cowe Bay.

TABLE 18.—PERMEABILITY OF 6 × 6 × 17-IN. CONCRETE PORTLAND CEMENT.

(1) Reference numbers.	(2) Proportion, by weight.	(3) Percentage of cement to total dry material.	(4) Kind of stone.	(5) Kind of sand.	(6) Maximum size of stone, in inches.	(7) Uniformly graded above given diameter, in inches.	(8) Percentage finer than diameter in Column 7.*	(9) Curve below diameter in Column 7.
155	1:9	10	J. P.	J. P.	2½	0.20	37.80	Ellipse.
151	1:9	10	"	"	1	0.10	35.90	"
165	1:9	10	"	"	½	0.075	36.30	"
168	1:2½:6½	10	"	"	2½	.....	.....	.....
167	1:3:6	10	"	"	2½	.....	.....	.....
172 B	1:2½:6½	10	"	"	1	.....	.....	.....
170	1:3:6	10	"	"	1	.....	.....	.....
192 B	1:2½:6½	10	"	"	½	.....	.....	.....
176 B	1:3:6	10	"	"	½	.....	.....	.....
187 A	1:9 uniform stone.	10	"	"	2½	0.20	37.8	Ellipse.
193 C	1:11.5	8	"	"	2½	0.20	37.8	"
179 B	1:7	12.5	"	"	2½	0.20	37.8	"
183 B	1:5¾	15	"	"	2½	0.20	37.8	"
217	1:8.4	10.6	C. B.	C. B.	2½	0.20	32.1	"
221	1:2.91:5.62	10.6	"	"	2½	.....	.....	.....
234	1:8.4	10.5	"	"	2½	0.20	37.8	Ellipse.
227	1:2.91:5.62	10.6	"	"	1	.....	.....	.....
233	1:10.8	8.5	"	"	2½	0.20	32.1	Ellipse.
224	1:6.5	13.75	"	"	2½	0.20	32.1	"
225	1:5.3	15.9	"	"	2½	0.20	32.1	"
213 C	1:8.8	10.2	J. P.	"	2½	0.20	33.8	"
219 B	1:8.8	10.2	"	"	2½	0.20	37.8	"
205	1:2.92:5.88	10.2	"	"	2½	.....	.....	.....
203 C	1:2.92:5.88	10.2	"	"	1	.....	.....	.....
207 C	1:2.92:5.88	10.2	"	"	½	.....	.....	.....
218	1:6.88	12.75	"	"	2½	0.20	33.8	Ellipse.
216	1:5.54	15.3	"	"	2½	0.20	33.8	"

* Including cement.

† In Cowe Bay mixtures the percentage of cement by weight is increased in Park material.

J. P. = Jerome Park; C. B. = Cowe Bay.

PRISMS, MADE OF VARIOUS AGGREGATES AND GIANT AGE, 3½ MONTHS.

(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
CALCULATED VOLUME, IN CUBIC FEET OF MATERIAL IN 1 CU. FT. OF BEAM, AS MADE.								RATE OF FLOW OF WATER, IN GRAMMES PER MINUTE.			
Cement.	Aggregate.	Total dry.	Water.	Total voids.	Total calculated volume.	Age, in days.	Time in which water appears, in minutes.	At 20 lb. per sq. in.	At 40 lb. per sq. in.	At 60 lb. per sq. in.	At 80 lb. per sq. in.
0.078	0.777	0.855	0.173	0.145	1.028	110	3	11.2	24.4	36.9	48.7
0.075	0.745	0.820	0.191	0.180	1.011	112	21	0	11.6	21.6	35.1
0.070	0.700	0.770	0.208	0.230	0.978	112	29	0	.....	20	36
0.076	0.758	0.834	0.154	0.166	0.988	119	20	0	3	8	12
0.074	0.738	0.812	0.144	0.188	0.956	113	3	15	27	46	.....
0.074	0.736	0.810	0.232	0.190	1.042	105	3.5	25	87	153	.....
0.070	0.730	0.802	0.226	0.198	1.028	119	7	8	18	31	49
0.070	0.703	0.773	0.224	0.227	0.997	137	25	0	13	35	63
0.070	0.702	0.772	0.199	0.228	0.971	101	24	0	19	34	50
0.077	0.775	0 852	0.154	0.148	1.006	119	3.75	14	21	27	33
0.060	0.771	0.831	0.170	0.169	1.001	140	7	25	161	237	273
0.087	0.755	0.852	0.189	0.148	1.041	107	3	15	22	30	38
0.130	0.715	0.845	0.186	0.155	1.031	105	5.5	5	8	10	12
0.079	0.776	0.855	0.133	0.145	0.988	146	17	1	3	5	6
0.076	0.750	0.826	0.157	0.174	0.983	133	134	0	0	0	0.7
0.079	0.781	0.860	0.147	0.140	1.007	147	72	0	0	1.9	3.9
0.077	0.755	0.832	0.173	0.168	1.005	150	125	0	0	0	1.8
0.064	0.807	0.871	0.154	0.129	1.025	147	3	14.7	25	37.6	42.7
0.100	0.765	0.865	0.149	0.135	1.014	151	100	0	0	0	0.5
0.129	0.738	0.867	0.147	0.133	1.014	151	98	0	0	0	1.4
0.080	0.793	0.873	0.152	0.127	1.025	137	8.75	4	11	17	23
0.078	0.772	0.850	0.160	0.150	1.010	116	45.5	0	1	2	3
0.075	0.740	0.815	0.160	0.185	0.975	132	7	1	4	8	12
0.075	0.745	0.820	0.156	0.180	0.976	132	26	0	5	10	15
0.070	0.703	0.773	0.195	0.227	0.968	132	29	0	10	17	25
0.099	0.767	0.867	0.151	0.133	1.017	148	10.5	2	2	3	3
0.117	0.735	0.852	0.154	0.148	1.006	147	.....	0	0	0.7	1.4

each case to balance the difference in specific gravity between this and the Jerome

Effect of Percentage of Cement Upon Permeability.

Conclusion 17.

The data in Table 18 which bear on this subject have been rearranged in Table 17. It is seen that the rate of flow is less as the percentage of cement increases, and in a much larger inverse ratio. The most extreme differences are shown in the straight Jerome Park materials, with which the rate of flow at 80 lb. pressure decreases from 273 g. per min. in the specimens having 8% of cement, to 12 g. per min. in the specimen having 15% of cement.

Effect of Size of Stone Upon Permeability.

Conclusion 18.

The data relating to this subject in Table 18 have been rearranged for more convenient reference in Table 19. It is seen that the evidence is conflicting, the mixtures with Cowe Bay material indicating that the rate of flow is less as the maximum size of the aggregate is greater, while the mixtures of Jerome Park material are erratic, the 1-in. and ½-in. stone giving about the same rate of flow, and the 2½-in. stone giving greater than either of the smaller sizes, but the results are much less definite than those of the other tests mentioned. All the straight Jerome Park specimens, in fact, are more erratic, as regards permeability, than the specimens containing more rounded grains which can be more uniformly mixed.

Decrease of Permeability with Age.—The rate of flow decreases materially with age. The difference in the age of the specimens in Table 18 is not sufficient to draw conclusions, but a comparison of these tests with those in Table 21, which were made under similar conditions, indicate a very great reduction in the flow from that at 1 month, to that at 3½ months.

Increase of Permeability with Pressure.—By the comparison in Table 18, of the values in Columns 19, 20 and 21, it is seen that the rate of flow increases nearly uniformly with the increase of pressure.

Effect of Thickness of Concrete Upon Permeability.—The data in Table 20 indicate that the rate of flow increases as the thickness of the concrete decreases, but in a much larger inverse ratio. All the tests in this table were made upon specimens from the same beam. Column 4 gives the results from a regular specimen

TABLE 19.—EFFECT OF SIZE OF STONE ON PERMEABILITY OF CONCRETE BEAMS.

No. of Beam.	Proportion, by weight.	Percentage of cement to total dry material.	Kind of Aggregate.		Maximum size of stone, in inches.	Time in which water appears, in minutes.	Rate of Flow of Water, in Grammes per Minute at the Following Pressures per Square Inch.			
			Stone.	Sand.			20 lb.	40 lb.	60 lb.	80 lb.
155	1:9	10	J. P.	J. P.	2¼	3	11	24	369	49
151	:9	10	"	"	1	21	0	12	22	35
165	1:9	10	"	"	½	29	0	..	20	36
168	$1:2^5:6^5$	10	J. P.	J. P.	2¼	20	0	3	8	12
172	$1:2^5:6^5$	10	"	"	1	3.5	25	87	153	..
192	$1:2^5:6^5$	10	"	"	½	2.5	0	13	35	63
167	1:3:6	10	J. P.	J. P.	2¼	3	15	27	46	..
170	1:3:6	10	"	"	1	7	8	18	31	49
176	1:3:6	10	"	"	½	24	0	19	34	50
221	$1:2^{21}:5^{22}$	10.6	C. B.	C. B.	2¼	134	0	0	0	0.7
227	$1:2^{21}:5^{22}$	10.6	"	"	1	125	0	0	0	1.8
205	$1:2^{22}:5^{28}$	10.2	J. P.	C. B.	2¼	7	1	4	8	12
203	$1:2^{22}:5^{28}$	10.2	"	"	1	26	0	5	10	15
207	$1:2^{22}:5^{28}$	10.2	"	"	½	29	0	10	17	20

J. P. = Jerome Park; C. B. = Cowe Bay.

TABLE 20.—COMPARATIVE PERMEABILITY OF CONCRETE THROUGH A LENGTH OF 8.5 INCHES *vs.* A LENGTH OF 17 INCHES. SPECIMEN NO. 224. COWE BAY AGGREGATES. PROPORTIONS, 1 : 6.5 (BY WEIGHT). AVERAGE AGE, 153 DAYS.

(1)	(2)	(3)	(4)	(5)
Pressure, in pounds per square inch.	Rate of Flow, in Grammes per Minute.			
	8.5 × 5.95 × 6.05-in. specimens.			17 × 5.95 × 6.15-in. specimen.
	(1)	(2)	Average.	
20	0.16	0.47	0.32	0
40	0.87	1.49	1.18	0
60	1.40	2.58	1.99	0
80	2.17	3.93	3.05	0.47

17 in. in length and Columns 2 and 3 the results from two specimens, each 8½ in. long, from the same beam. The difference in the permeability of 1 and 2 is greater than would be expected from two similar specimens, but this is probably explained by differences

in homogeneity due to the large size of stone used for such a short specimen, and to the fact that the length of the two pieces which were broken from larger ones may not have been absolutely the same. Evidently, further comparative tests of similar specimens are required.

Rate of Flow During a Four-Hour Period.—A specimen subjected to continuous uniform pressure for a period of 4 hours shows a practically uniform rate of flow during this time. The results are given in Table 21.

TABLE 21.—UNIFORMITY OF RATE OF FLOW THROUGH A SPECIMEN OF 1 : 2.5 : 6.5 (BY WEIGHT). CONCRETE SPECIMEN NO. 168. 5.8 × 5.9 × 17.0 INCHES LONG. JEROME PARK SCREENINGS AND STONE. AGE, 119 DAYS.

(1)	(2)	(3)	(4)	(5)
Time, in hours and minutes.	Pressure, in pounds per square inch.	Water passing, in grammes.	Rate of flow per minute, in grammes.	Rate of flow per hour, in grammes.
0	60	0	.....	.....
1:00	"	446	.....	446
1:05	"	42	8.4	.....
1:10	"	40	8.0	.....
1:15	"	41	8.2	.....
2:00	"	344	7.6	467
2:05	"	40	8.0	.....
2:10	"	40	8.0	.....
2:15	"	40	8.0	.....
3:00	"	338	7.5	458
3:05	"	40	8.0	.....
3:10	"	39	7.8	.....
3:15	"	40	8.0	.....
4:00	"	347	7.7	466

VOLUMETRIC TESTS OF DENSITY OF NEAT CEMENT AND MORTAR.

During the progress of the experiments at Jerome Park, frequent tests were made of the density of the cement which was being used, and also of the densities of various mortars. For this purpose, the cylinder apparatus described for the density experiment upon concrete was used; tests were also made upon a smaller scale, with a 200 c. c. graduate for the mould. The apparatus used for these tests on the small scale, and the Jackson specific gravity flask, also constantly used, are shown in Fig. 1, Plate XVI.

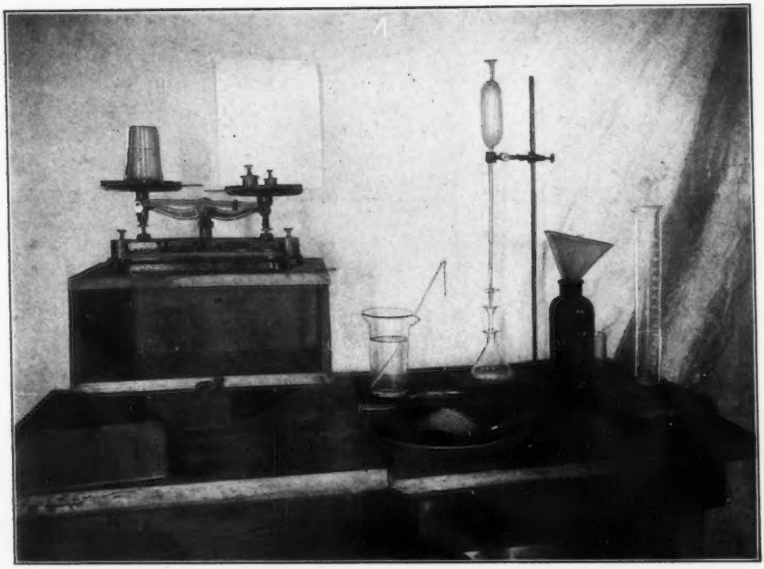


FIG. 1.—APPARATUS FOR VOLUMETRIC TESTS OF DENSITY OF CONCRETE.

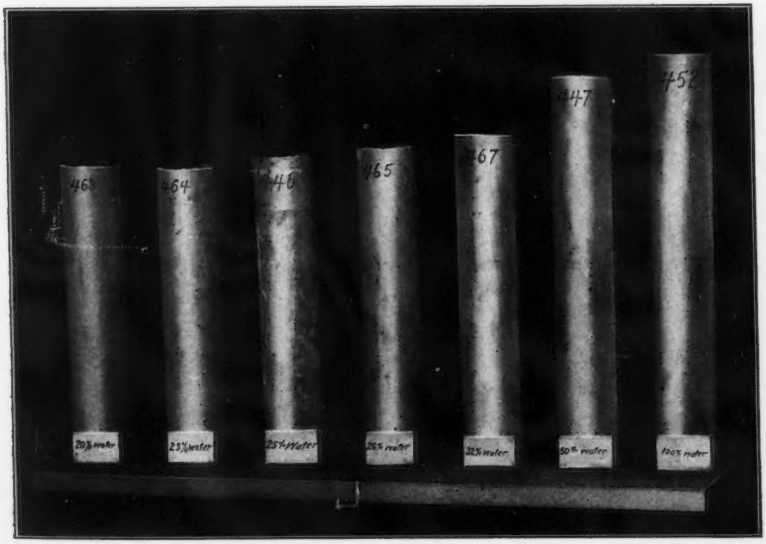


FIG. 2.—VARIATION IN VOLUME OF PASTE PRODUCED BY MIXING THE SAME WEIGHT OF CEMENT WITH DIFFERENT PERCENTAGES OF WATER.

Effect of Different Percentages of Water Upon Volume and Density of Portland Cement Mortars and Concretes.

Table 22 and Fig. 2, Plate XVI, illustrate the variation in volume of paste produced from the same weight of the same cement with different percentages of water. They also show the difference in volume between the fresh paste as mixed and the same paste after standing for a period of about 3 hours and being compacted by occasionally shaking and tapping the mould. The tests were made in the graduates, as previously described. By adopting a standard method in all the tests, and maintaining a uniform consistency, good results were obtained. When sand is mixed with the cement, there is much less variation in the volumes of the mortars due to different percentages of water than in neat pastes, but the variation is generally very appreciable, although less with coarse than with fine sands.

TABLE 22.—Effect of Different Percentages of Cement Upon the Volume of Neat Portland Cement Paste.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Experiment number.	Nominal mix.	Kind of cement.	Weight of cement, in grammes.	Water used in mixing, in grammes.	Percentage of water used in mixing.	Volume of Paste.		Absolute Volume.			
								Fresh.		Finally compacted.	
						Fresh, in cubic centimeters.	Finally compacted, in cubic centimeters.	Water.	Cement (density).	Water.	Cement, (density).
								w.	*c.*	*w.*	*c.*
463	Neat.	Giant.	300	60	20	165.8	163.8	0.362	0.584	0.354	0.590
464	"	"	300	69	23	168.7	167.7	0.391	0.546	0.404	0.574
465	"	"	300	78	26	174.0	172.3	0.438	0.543	0.441	0.560
467	"	"	300	96	32	183.2	179.3	0.504	0.508	0.508	0.534
447	"	"	300	150	50	244.0	221.0	0.618	0 395	0.571	0.435
449	"	"	300	300	100	390.6	214.3	0.772	0.248	0.569	0.436

The resulting volumes of different concretes, of the same materials and proportions, but with varying percentages of water are nearly constant, provided sufficient water is added to permit thorough compacting. When an excess of water is used, it is nearly all expelled as the solid materials settle by gravity. There is, however, a slight variation even in concrete. A dry mixture, pro-

vided sufficient water is added to rise to the top on hard ramming, can be compacted somewhat more than a concrete of medium consistency, while a very wet concrete is apt to occupy a very slightly larger volume, and hence be less compact than a medium concrete. In most cases, the difference between the medium and very wet mixtures is only noticeable by extremely accurate measurements.

Elasticity Tests.

Figs. 14, 15, and 16 show a number of typical results of tests of elasticity of several of the capped prisms. These tests were made at the Stevens Institute. Readings of compressive deformations were taken at increments corresponding to unit increments of 100 lb., and in most of the tests the load was released at 500 and 1 000 lb. and the permanent set recorded. In a few cases, shown by zigzag lines, the effect of repeated stress was also measured. The results are given in Table 23.

It should be noticed in the diagrams that nearly all the curves run up sharply from 100 lb., the first load applied, indicating that the modulus between 100 and 200 lb. is not greater than at the next higher loadings. After deducting the set, the deformation (shown by the curve labeled "Elastic"), in the majority of the specimens, at first increases uniformly, the curve being in these cases a straight line in its lower portion. The point of tangency with the decided curve is sometimes considered the elastic limit of the concrete.

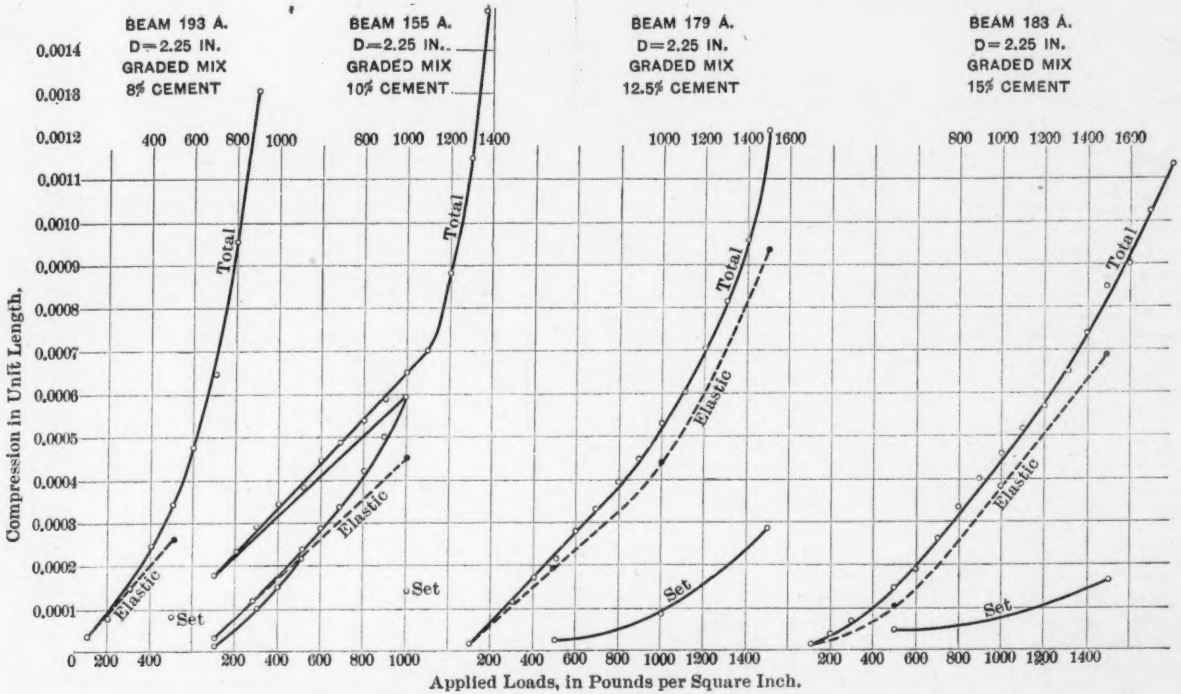
The table shows several interesting comparisons:

1.—The modulus increases with the maximum size of stone. Compare, respectively, specimens 1, 2, 3; 5, 6, 7; 17, 18; 22, 24.

2.—The modulus increases with the percentage of cement. Compare, respectively, 8, 9, 10, 11; 13, 14, 15, 16; 19, 20, 21. There are one or two exceptions to this rule, but the general trend is unquestionable.

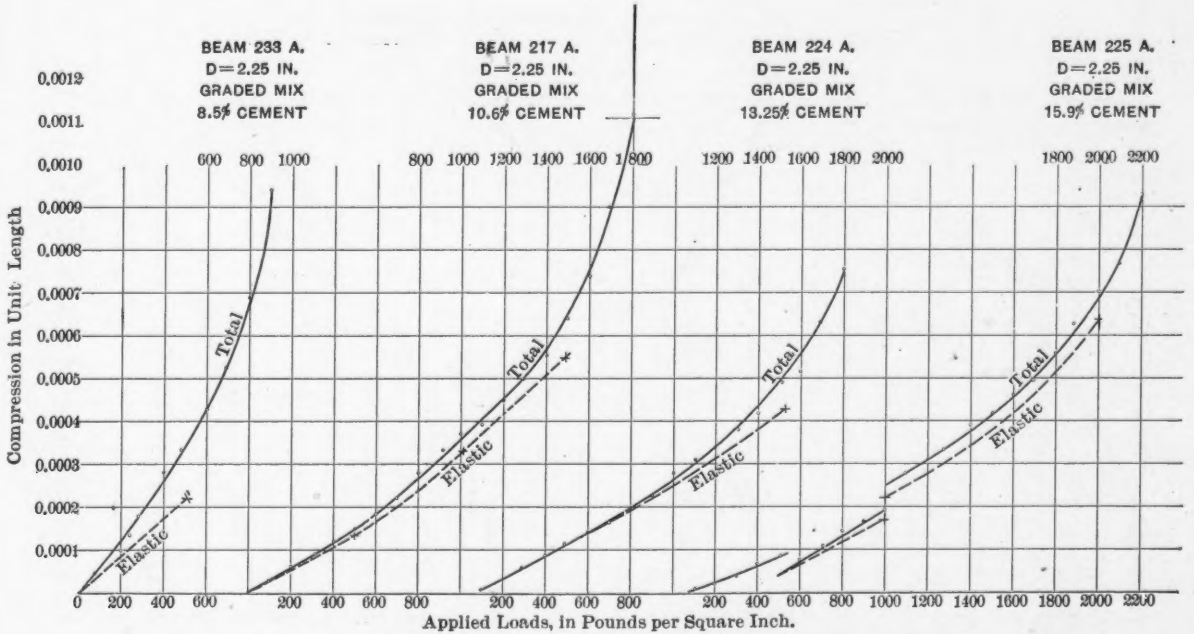
3.—In general the modulus of the Cowe Bay gravel and sand is higher than the modulus of similar specimens mixed with Jerome Park sand and screenings.

4.—The modulus of specimens with a mixture of Jerome Park stone and Cowe Bay sand is in general slightly lower than similar specimens of straight Cowe Bay material.



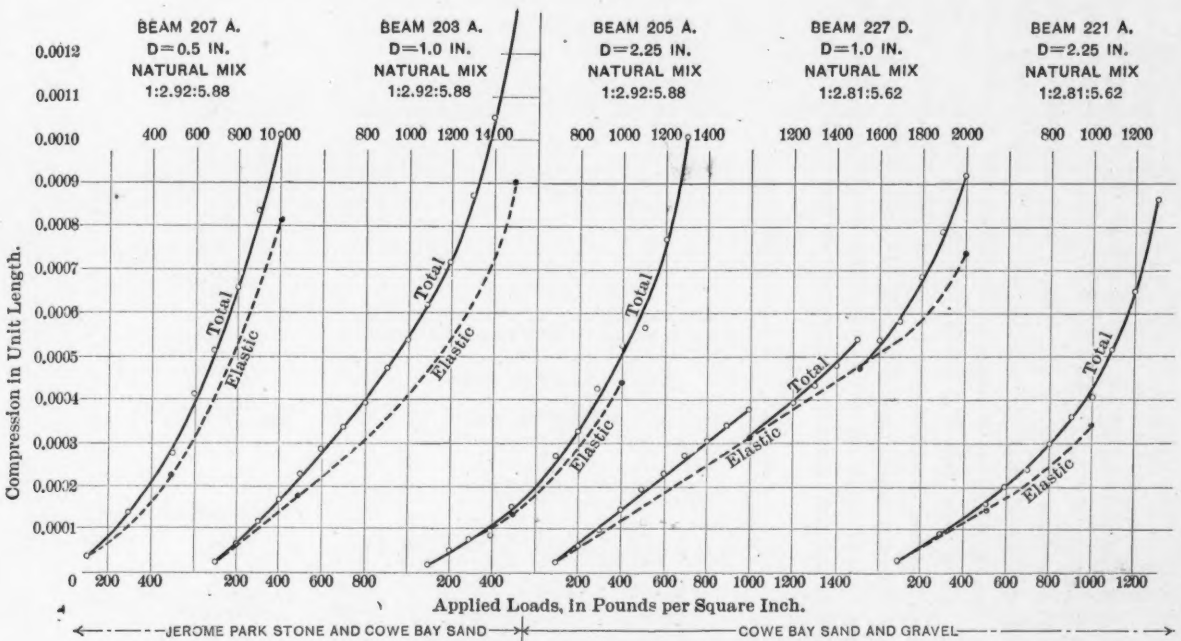
TOTAL AND ELASTIC COMPRESSION OF 6 BY 6 BY 18 IN. CONCRETE PRISMS MADE OF GIANT PORTLAND CEMENT AND JEROME PARK SCREENINGS AND BROKEN STONE. AGE, ABOUT 140 DAYS.

FIG. 14.



TOTAL AND ELASTIC COMPRESSION OF 6 BY 6 BY 18-IN. CONCRETE PRISMS MADE OF GIANT PORTLAND CEMENT AND COWE BAY SAND AND GRAVEL. AVERAGE AGE, ABOUT 140 DAYS.

FIG. 15.



TOTAL AND ELASTIC COMPRESSION OF 6 BY 6 BY 18-IN. CONCRETE PRISMS MADE OF GIANT PORTLAND CEMENT AND VARIOUS AGGREGATES. AGE, ABOUT 140 DAYS.

FIG. 16.

TABLE 23.—MODULUS OF ELASTICITY OF CONCRETE PRISMS.

Tests for deformation. Jerome Park Reservoir. 1905.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Reference number.	Beam number.	Proportion, by weight.	Percentage of cement to total dry material.	Kind of stone.	Kind of sand.	Maximum size of stone, in inches.	Uniformly graded above diameter, in inches.	Percentage finer than diameter in Column 8.	Density.	Ultimate strength, in pounds per square inch.	Modulus of elasticity, in pounds per square inch.	Modulus taken between limits, in pounds per square inch.
1	155A	1:9	10	J. P.	J. P.	2.25	0.20	37.8	0.855	1 425	2 143 000	100—1 000
2	151A	1:9	10	"	"	1.00	0.10	35.9	0.820	1 085	1 702 030	100— 500
3	165A	1:9	10	"	"	0.50	0.075	36.3	0.770	960	1 436 000	100— 500
4	192A	$1:2^{3}:6^{5}$	10	"	"	0.50	Natural Mix		0.773	875	1 274 000	300— 500
5	167	1:3:6	10	"	"	2.25	"	"	0.812	965	2 425 000	100— 500
6	170A	1:3:6	10	"	"	1.00	"	"	0.802	860	1 798 000	100— 500
7	176A	1:3:6	10	"	"	0.50	"	"	0.772	670	878 000	200— 500
8	193A	$1:11^{5}$	8	"	"	2.25	0.20	37.8	0.831	940	1 750 000	100— 500
9	155A*	1:9	10	"	"	2.25	0.20	37.8	0.855	1 425	2 143 000	100—1 000
10	179A	1:7	12.5	"	"	2.25	0.20	37.8	0.852	1 710	2 250 000	200— 800
11	183A	$1:5^{67}$	15	"	"	2.25	0.20	37.8	0.845	1 920	4 650 000	100— 500
12	234D	$1:8^{43}$	10.6	C. B.	C. B.	2.25	0.20	37.8	0.860	1 800	2 867 000	100—1 500
13	233A	$1:10^{76}$	8.5	"	"	2.25	0.20	32.1	0.871	940	2 252 000	100— 500
14	217A	$1:8^{43}$	10.6	"	"	2.25	0.20	32.1	0.855	1 880	3 920 000	100— 500
15	224A	$1:6^{51}$	13.25	"	"	2.25	0.20	32.1	0.865	2 110	3 675 000	100—1 000
16	225A	$1:5^{30}$	15.9	"	"	2.25	0.20	32.1	0.867	2 315	4 273 000	500—1 000
17	221A	$1:2^{81}:5^{62}$	10.6	"	"	2.25	Natural Mix		0.826	1 455	3 260 000	100 – 600
18	227D	$1:2^{81}:5^{62}$	10.6	"	"	1.00	"	"	0.832	2 065	3 100 000	100—1 500
19	213A	$1:8^{30}$	10.2	J. P.	"	2.25	0.20	33.8	0.873	2 000	3 480 000	100— 500
20	218A	$1:6^{27}$	12.75	"	"	2.25	0.20	33.8	0.866	2 150	3 830 000	100— 800
21	216A	$1:5^{54}$	15.3	"	"	2.25	0.20	33.8	0.852	2 440	3 508 000	200—1 000
22	205A	$1:2^{92}:5^{88}$	10.2	"	"	2.25	Natural Mix		0.831	1 480	3 037 000	300— 500
23	203A	$1:2^{92}:5^{88}$	10.2	"	"	1.00	"	"	0.820	1 555	2 550 000	100— 700
24	207A	$1:2^{92}:5^{88}$	10.2	"	"	0.50	"	"	0.783	1 145	2 206 000	100— 400

* Beam 155 repeated here to facilitate comparison.
J. P. = Jerome Park; C. B. = Cowe Bay.

In conclusion the writers desire to express to their assistants in this work their hearty appreciation of their interest and zeal, without which co-operation the results accomplished with the time and funds available would have been impossible. Especial thanks are due to Thomas H. Wiggin, Assoc. M. Am. Soc. C. E., for his valued advice and assistance in starting the experiments; to William Hauck, Assoc. M. Am. Soc. C. E., for his careful attention to the large number of calculations involved in the tables of this paper, and to James L. Davis, Assoc. M. Am. Soc. C. E., and Messrs. Charles M. Montgomery, and William E. King, for their faithful labors in connection with the tests.

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PAPERS AND DISCUSSIONS.

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THE EFFECTS OF THE SAN FRANCISCO EARTHQUAKE OF APRIL 18TH, 1906, ON ENGINEERING CONSTRUCTIONS.

REPORTS OF A GENERAL COMMITTEE AND OF SIX SPECIAL COMMITTEES OF THE SAN FRANCISCO ASSOCIATION OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

REPORT OF GENERAL COMMITTEE.

EDWIN DURYEA, JR., *Chairman;* C. D. MARX, FRANKLIN RIFFLE, ARTHUR L. ADAMS AND WILLIAM W. HARTS.

TO BE PRESENTED MAY 1ST, 1907.

Immediately after the earthquake of April 18th, 1906, and the destruction of San Francisco by the resulting fire, it was obvious that the assistance of skilled engineers could be of great value in planning the reconstruction of the city on new and better lines, and that valuable professional lessons would be learned by careful study of the effects of the earthquake and fire on various engineering constructions. By virtue of its technical membership, the San Francisco Association of Members of the American Society of Civil Engineers seemed to be a fitting organization through which to proffer assistance to the municipal authorities, to study the

NOTE.—This report and the reports to which it refers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and when finally closed, the reports, with discussion in full, will be published in *Transactions*.

effects of the earthquake and fire, and to collect technical information. Therefore, on April 28th, ten days after the earthquake, a meeting of the Association was held in Oakland to form an organization for these purposes.

At this meeting the work was outlined in the two general divisions: First, Plans for Reconstruction; and second, Effects of the Earthquake and Fire, as showing Needed Improvements in Structural Design. The Board of Direction of the Association ordered that an offer of the services of the Association be made to the Mayor of San Francisco, to assist him in any way desired. A number of committees were also appointed at that time to study the earthquake effects on various classes of structures.

In compliance with the Board's order, the aid of the Association was proffered to the Mayor through its President on the same afternoon, and, at the Mayor's suggestion, again in public at a meeting of the Committee of Sixty on Monday, April 30th.

Preparations for organizing the Committee of Forty on Reconstruction were already far advanced, however, and hence the assistance of the Association as an organization was not asked for by the Municipal Authorities. The Association, as a body, therefore, had no opportunity to assist in the plans for the reconstruction of the city. The Mayor, however, placed the following individual members on the Committee of Forty, as members of the sub-committees named below, so that, in effect, the Association tion of the city. The Mayor, however, placed the following instruction as were made at that time:

On the Sub-committee on Water Supply and Fire Protection.—Messrs. C. H. McKinstry, V. G. Bogue, A. M. Hunt, C. D. Marx, Edwin Duryea, Jr., and Marsden Manson.

On the Sub-committee on Reservoirs and Parks.—Mr. Marsden Manson.

*On the Sub-committee on Street-Widenings and Extensions.**—Messrs. V. G. Bogue, and Edwin Duryea, Jr.

On the Sub-committee on Statistics.—Messrs. Marsden Manson, C. H. McKinstry, V. G. Bogue, and Edwin Duryea, Jr.

On the Revision of Building Laws.—Mr. J. D. Galloway.

On the Committee of Sixty.—In the first few days after the

* William Hood, M. Am. Soc. C. E. (not a member of the Association, or of the Committee of Forty), also joined in the work of this sub-committee, by invitation.

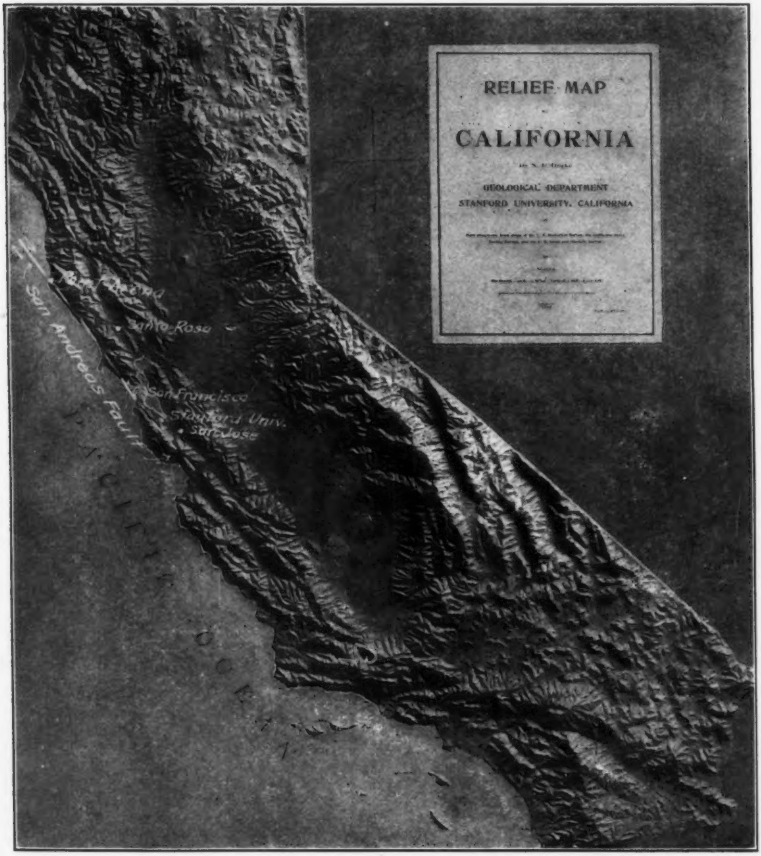


FIG. 1.—RELIEF MAP OF CALIFORNIA.

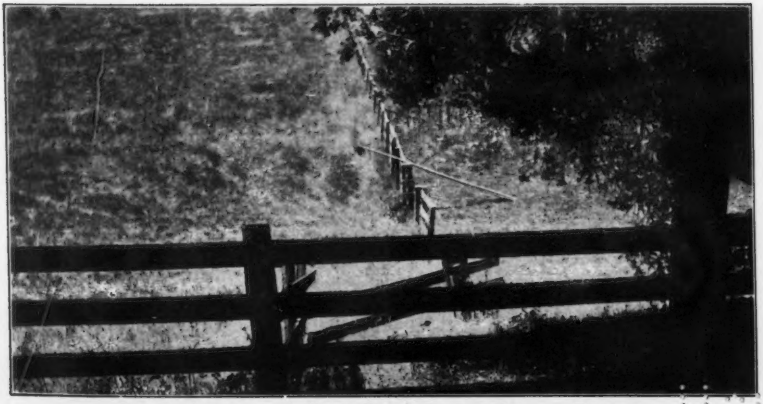


FIG. 2.—OFFSET OF 8 FT. IN FENCE LINE IN PORTOLA VALLEY.

fire, very important aid was rendered to the city by two members of the Association, Messrs. George L. Dillman and A. M. Hunt, the former having been in charge of the emergency restoration of the water-supply, and the latter of the emergency restoration of lighting and transportation.

The Association, not being needed to aid the city as a body, then devoted its whole attention to the second phase of the subject: A study of the earthquake effects, as showing needed improvements in the design of engineering works. At the first meeting, April 28th, several committees were appointed by the Board of Direction for this purpose. The personnel of these committees, as afterward completed, is given at the beginning of the report of each committee.

Through these committees, the Association has studied the physical effects of the earthquake and fire, with the results shown in the accompanying committee reports. It is believed that the data thus gathered and the conclusions deduced therefrom are of permanent benefit to the profession, and therefore they are presented for publication in the records of the Society. It is believed that after publication there will be a full discussion of the several subjects by the members of the Association in San Francisco, as well as by the Society. As far as practicable, all questions dealing with the earthquake effects will be answered by members of the Association who have had special opportunities for observing the facts.

Before closing the report of the General Committee, it seems proper to give a brief abstract of the conclusions reached by each committee.

It must be understood that the Association, as a body, is not responsible for the conclusions reached by the several Committees, and that the General Committee does not necessarily concur in all of them. Differences of opinion are sure to exist, and will no doubt be brought out fully in the discussion.

Committee on Geology.*

(1)—"The earthquake of April 18th, 1906, was due to the relief of accumulating stresses in the earth's crust, by a movement along a previously known fault-plane."

* The personnel of this and other Committees mentioned in this report is given with the reports of each Committee, printed in the following pages.

(2)—"While the time of occurrence of such movements cannot be predicted, the relief of the accumulated stresses gives reasonable assurance of freedom (within the area affected) from a recurrence of earthquakes of similar intensity, for some time—probably at least fifty years."

(3)—"By reason of the existence of this and many other fault-lines in California, through the agency of which stresses may be relieved when they reach the danger-point, earthquakes of greater intensity than the recent one are hardly to be expected even in the remote future."

(4)—"The disastrous results following the recent earthquake * * * were largely due to a lack of safe construction, as ordinarily understood; and, if the lessons which may be drawn from it are followed in the future, it is believed that the Pacific Coast can be made safe as a habitation and field of investment, as far as earthquakes may affect conditions."

COMMITTEE ON BUILDINGS.

(1)—*Earthquake Effects.*—"Sufficient evidence is at hand to warrant the statement that a building designed with a proper system of bracing to withstand wind at a pressure of 30 lb. per sq. ft. will resist safely the stresses caused by a shock of an intensity equal to that of the recent earthquake."

"The prime requisite of the structure is elasticity. * * * To this requirement, the building with a timber or steel frame answers very well. The reinforced concrete structure does so also, with * * * exceptions * * *. The building with stone, brick or block construction, having horizontal mortar joints, does not answer the requirement at all. It may be stated, as one of the most obvious lessons of the earthquake, that brick walls, or walls of brick faced with stone, when without an interior frame of steel, are hopelessly inadequate. As a method of building in earthquake countries, such types are completely discredited."

"Foundations did not suffer at all, no instances of any damage having come to hand. * * * The evidence is that foundations well built, along accepted lines, are adequate."

"It may be questioned whether difference in workmanship was not responsible for many of the results. While it is true that good workmanship gave better results than ordinary, it is still the opinion of the writers that it was mainly a question of design. * * * Speaking generally, buildings of brick walls and wooden interiors cannot be built which will not be wrecked in a severe shock, it being a fault of design and not of materials or workmanship."

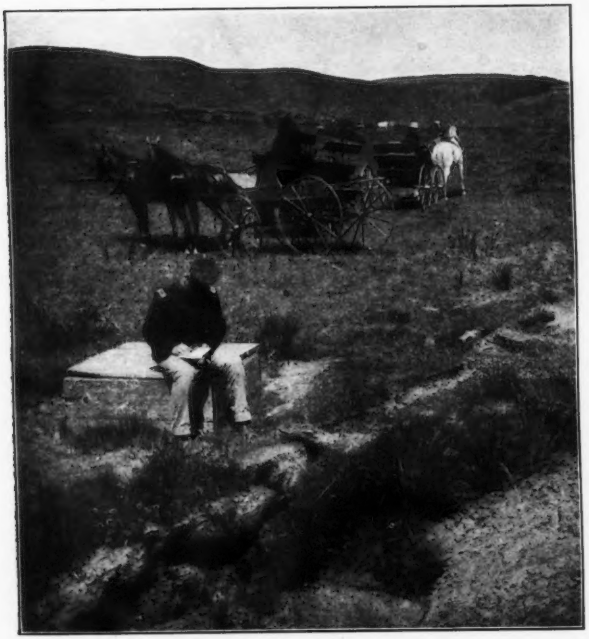


FIG. 1.—FURROW ALONG FAULT LINE NEAR SAN ANDREAS RESERVOIR.



FIG. 2.—DISPLACEMENT OF SOIL IN VALLEY OF PAJARO RIVER. THIS IS NOT ON THE FAULT LINE, BUT SHOWS THE CHARACTER OF SETTLEMENTS IN ALLUVIAL DEPOSITS.

(2)—*Damage by the Fire.*—"All materials were destroyed when directly exposed to the fire for any length of time. Brick, terra cotta, granite, marble, sandstone, steel, cast iron, concrete, plaster, cement, timber—all failed. Especial emphasis is placed on this point. Anyone with an interst in any one material can find evidence to support a claim for it; yet, impartial observation leads to the conclusion that, when a material was subjected to what would be considered a test fire, it was destroyed."

"No foundations were found injured by the fire."

"The steel frames were the least injured of any part of the various structures. Where properly protected, there was no injury. Where the protection was faulty, or where there was none, the destruction was complete."

"A logical deduction from the statement that all materials were destroyed is the conclusion that all structural parts of a building, of whatever material constructed, must be protected by another material which will be a more or less complete loss in a fire. This applies to a steel frame, to floors of any type, and to roofs. It is impossible to protect some parts, such as fronts, partitions, and other parts directly exposed."

"Any deductions from the fire must be those based upon a general conflagration, and not those of an isolated fire. In view of the complete destruction of all material, it becomes a question as to what should be done to make a building fire-proof. * * * The only statement that can be offered is that the best insurance for buildings would be the isolation of a district containing nothing but fire-proof structures. A general conflagration would then be impossible."

COMMITTEE ON WATER-WORKS.

"*First.*—That greater attention in the future should be given to the avoidance, when possible, of threatening geologic faults, in the location of important water-works structures, than has sometimes been given in the past."

"*Second.*—That skillfully designed and well-built earthen dams are structures proven by the great earthquake of April 18th, 1906, to be of great stability, and deserving of increased confidence."

"*Third.*—That concrete dams of gravity section are able to withstand earthquake shocks of great severity without damage."

"*Fourth.*—That distributing reservoirs, pumping machinery, elevated tanks and stand-pipes, if made secure as to foundations, and intelligently designed along lines of the best accepted practice, will be found capable of withstanding earthquake shocks sufficiently severe to work the general destruction of most buildings."

"*Fifth.*—That pipe lines or conduits, of any character whatever,

are almost certain to fail when intersected by a plane of large movement, whether that movement be in the nature of a faulting, or of a sliding or settling of the earth in consequence of earthquake shock; and that in choosing locations for such structures it is prudent, as far as practicable, to avoid localities subject to such movements."

"That in planning distributing systems for cities, the important supply pipes should be located along routes carefully selected for stability; and that areas liable to serious disturbance should be so segregated in the piping system as to make them easily and quickly separable from the remainder of the system."

"*Sixth.*—That close adherence should be given to the recognized standards of the best present practice, such as the use in distributing systems of an abundance of suitably placed gates for isolating different pipes and different sections; the preservation of such gates in working condition; and having their location easily ascertainable, both in the street and from the office records; the duplication, along widely separated routes, of the critically important main supply pipes; the maintenance in as close proximity as may be to the centers of use of an ample storage supply of water; and the use of types of substantial design in working out plans for structures subject to possible earthquake shock."

COMMITTEE ON LIGHTING AND STREET-RAILWAY TRANSPORTATION.

"The injury caused to the street-car tracks was relatively slight," and only "on ground that had been filled."

"The slots of cable roads * * * (with few exceptions) were found closed * * * only in the burned district, and the evidence points to its being due mainly to expansion caused by the excessive heat. The fact that the Geary Street Line, which is a cable road, operated for several hours after the earthquake, is very pertinent." The cable roads, however, were put entirely out of use by the fire and the falling debris.

"Many of the trolley lines outside of the burned district * * * could have been operated at any time," except for "the fire-hazard from the tangle of other wires. The trolley lines unquestionably substantiate the claim that such a system is flexible, and admits of emergency work to an extent not equalled by any other."

The street-railroad power-houses were but little injured except by the falling of a brick stack and the collapse of a roof. "Brick stacks * * * were in most instances broken off, while well-guyed steel stacks stood without injury."

With one exception, "the various gas-works were uninjured. The damage to mains was principally due to explosions. As ser-



FIG. 1.—EARTHQUAKE DAMAGE TO COLONNADES, STANFORD UNIVERSITY. NOTE CONSTRUCTION OF SPANDRELS.

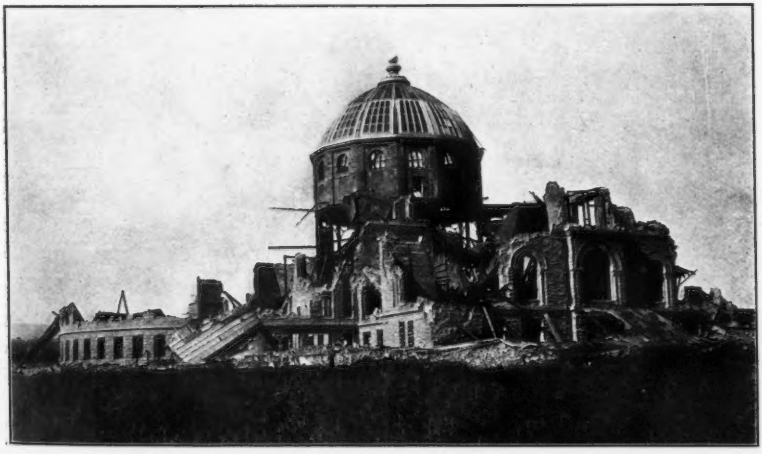


FIG. 2.—EARTHQUAKE DAMAGE TO LIBRARY OF STANFORD UNIVERSITY.

vice was gradually restored, it was found that the house pipes, except in very few instances, were not damaged."

Electric lighting plants were but little injured by the earthquake, but the fire destroyed many sub-stations and overhead distributing lines. "The underground conduit system and the Edison tubing came through both earthquake and fire in very good shape."

Committee on Sewers.*

No report has as yet been made by this committee, it is said because the injury to sewers cannot be known conclusively until after the first heavy rain. From a letter† written by H. D. Connick, one of the members of the committee, and the Assistant Engineer in charge of San Francisco's sewers, the following information is condensed:

In the rocky portions of San Francisco the sewers were not affected. In portions where the rock was overlaid with sand, there were no permanent displacements except where the original ground supported a fill; in such areas settlements occurred, and the sewers were destroyed. In filled-in tidal areas, marsh-lands and swamps there was considerable movement in a number of places (the greatest near 16th St. and Valencia St., where the settlement was 5 ft. and the lateral movement 6 ft.) and in all such disturbed areas the sewers were destroyed.

All the masonry sewers injured, with one exception, were constructed, a number of years ago, of brick laid in a poor quality of lime mortar—in fact, in many old sewers there is nothing but sand in the joints of the brickwork.

In San Francisco a reinforced concrete sewer, on a pile foundation, where the ground does not furnish suitable support, will probably give the best satisfaction.

It is believed that $100 000 will cover the total damage to the San Francisco sewers by the earthquake.

Committee on Railway Structures.

"The structures peculiar to railroads which were affected, are embankments, trestles, bridges, tunnels, and water and oil tanks."

Embankments.—These settled more or less where they crossed marshes or were underlaid by soft strata. In one instance (across a tule marsh) the settlement was as much as 11 ft., while in another case (miles from the fault) a settlement of only 6 in. was accompanied by a horizontal displacement of 3 ft.

Trestles.—The damage to trestles was small, except on the North

* This Committee consisted of Messrs. Marsden Manson, H. Kower, and H. D. Connick.

† *Engineering News*, September 20th, 1906.

Shore Railroad, where a trestle of framed bents on piles, 600 ft. long and 70 ft. high, was thrown down, and portions of another trestle were thrown entirely off the piles, the piles themselves being moved down stream. These trestles were across soft ground, and near the fault-line.

Bridges.—"Draw-bridges * * * around San Francisco Bay, being generally on soft ground, were affected by a slight movement of their piers, in many cases resulting in the bridge binding so that it could not be opened until some repairs were made."

"A steel draw-bridge, over Petaluma Creek, was open at the time of the earthquake, and was thrown off its center 2 ft. to the east and 1 ft. to the north. It was a 220-ft. span, and on four iron cylinders, filled with concrete, on pile foundations."

Fixed spans, with a few exceptions, were not affected seriously. Where affected it was by a movement of the piers or abutments relatively to each other.

Tunnels.—"In general, tunnels seem to have been affected only by the displacement or loosening of the material in the sides and roof, caused by the shaking of the ground. The effect of this was to crush the timbers."

"The new tunnels being constructed by the Southern Pacific Railroad on the Bay Shore line, in the southern part of San Francisco, were not injured at all."

Tanks.—"Several tanks on the different roads were thrown down. In all cases, however, these were on wooden or cast-iron frames, not braced to withstand the twisting motion which accompanied this earthquake. Tanks on riveted frames did not fall, though in several instances they were severely damaged and thrown out of plumb."

Overturned Cars, etc.—"At Chittenden Station, * * * three standing box-cars, two of them loaded, were turned over."

"A narrow-gauge passenger train, consisting of engine and three cars, standing on the track at Point Reyes, was thrown over on its side."

"A freight-train, running near Chittenden Station, was derailed."

Committee on Highway Structures.

No final report has as yet been received from this committee. As far as ascertained, the earthquake did very little damage to highway bridges.

The reports in full of the several committees appointed as stated in this report will be found in the Appendix. It is hoped they will bring out a full discussion from engineers who are interested in the effects of earthquakes on engineering structures.



FIG. 1.- EARTHQUAKE DAMAGE TO LIBRARY OF STANFORD UNIVERSITY.

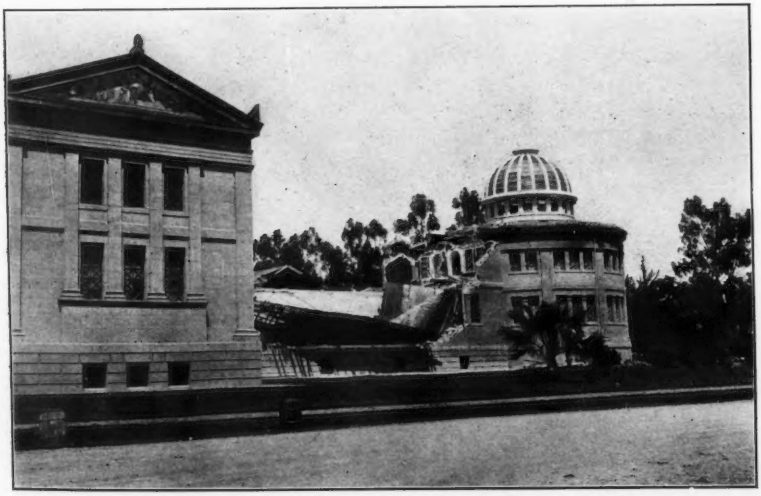


FIG. 2.—EARTHQUAKE DAMAGE TO MUSEUM OF STANFORD UNIVERSITY. REINFORCED CONCRETE SECTION ON THE LEFT, WITH CONNECTING PORTION OF BRICK IN THE CENTER AND ON THE RIGHT.

APPENDIX A.

REPORT OF COMMITTEE ON THE GEOLOGY OF THE EARTHQUAKE.

COMMITTEE:
H. L. HAEHL, OTTO VON GELDERN, LUTHER WAGONER, C. E. GILMAN.

At 5.12 A. M. on April 18th, 1906, a violent earthquake shock was felt throughout the western portion of Central California. The shock lasted about one minute, and it has been followed, to date (August, 1906), by a series of lesser shocks gradually diminishing in intensity and frequency. Much damage was done to buildings by the first shock (particularly in San Francisco, Santa Rosa, San José, and Stanford University), and several hundred lives were lost. Disastrous fires broke out in San Francisco and in Santa Rosa, and the damage from earthquake was multiplied many times by their ravages.

The damage to buildings, while large, was confined to those faulty either in design or in construction. Carelessness in fulfilling contracts, and inadequate building inspection, are responsible for most of the loss by earthquake. Aside from the injuries to, and by reason of, the structures of Man, there is nothing to indicate a calamity, except, perhaps, on the fault line, to be hereafter described. The face of the earth is unchanged, and neither vegetable nor animal life has suffered. The results, so disastrous to buildings and engineering structures, can and will be provided against in the future, and a study of the geological elements of the disturbance reveals no reason why California need expect earthquakes of such intensity as to render structures dangerous, if properly designed and honestly built. Luckily, the cause of the earthquake is now well known, and was, indeed, immediately suspected by all geologists familiar with the geology of the Coast region.

It is known that the earth's crust has been and is now being distorted, fractured and displaced; but geologists deal with a unit of time which is beyond the ordinary comprehension, and it is only occasionally that an acceleration of these movements brings them fairly before the lay mind, and calls attention to the fact that, while we have been considering the earth as something fixed and stable, stability is only a relative term.

Many theories have been advanced to explain the phenomena of earth movement; in fact, the causes themselves are probably many in number, complex in character, and but imperfectly under-

stood. Movements not accompanied by volcanic phenomena (tectonic) are believed by some to be due to the contraction of the earth's crust in cooling, while others hold that they are due to the expansion of the surface by reason of heat rising from within. The transportation of enormous quantities of material from one portion of the earth's crust to another by the denuding and depositing action of streams is also believed gradually to set up strains in the earth's strata which in the end cause fracture and movement. The idea that barometric pressure and the moon's phases are causes of earth fractures and the resulting earthquakes has been abandoned; yet scientists feel that tidal strains due to the attraction of terrestrial bodies may at times at least assist in bringing about earth movements.

Whatever the causes, it is certainly clear that in the earth's crust stresses exist which accumulate to the point of breaking the strata and causing distinct movements, sometimes slow and uniform, and sometimes rapid and spasmodic. The more rapid movements are classed under three heads:

First.—Volcanic disturbances, explosive in character, due probably to the explosion or condensation of gases which accumulate beneath the earth crust, and confined to areas of volcanic activity.

Second.—The breaking of strata under stresses. Evidences of this are common. Beds originally deposited in horizontal layers are found up-tilted at all angles, and sometimes completely reversed in sharp, closely pressed folds.

Third.—Rock masses slipping one against another, either horizontally or vertically, along planes of fracture or faulting. These fault planes extend into the earth to unknown depths, and the lines of faulting can often be traced for hundreds of miles along its surface. They are the safety valves of their particular localities; the lines of weakness, or of least resistance, along which the accumulating strains of the earth's crust are relieved.

It was a horizontal movement of this last type, along a well-known fault line, which set up the vibrations of the earth's crust which constituted the earthquake of April 18th. It should be borne in mind that there is a marked distinction between an earth movement, as here referred to, and an earthquake. They are cause and effect. The recent earth movement along the particular fault line responsible for the location of the earthquake has been observed to be as great as 10 to 20 ft., measured by offsets in fences and roads, yet the amplitude of the resulting earthquake at Mount Hamilton, 13 miles east of San José, recorded by the seismographic apparatus of the Lick Observatory was only 2.03 in. The earth movement is believed to have been felt in San Francisco and Oakland as a gentle shifting to the southeast, probably coincident with

PLATE XXI.
PAPERS, AM. SOC. C. E.
MARCH, 1907.
REPORTS OF COMMITTEES ON
SAN FRANCISCO EARTHQUAKE.

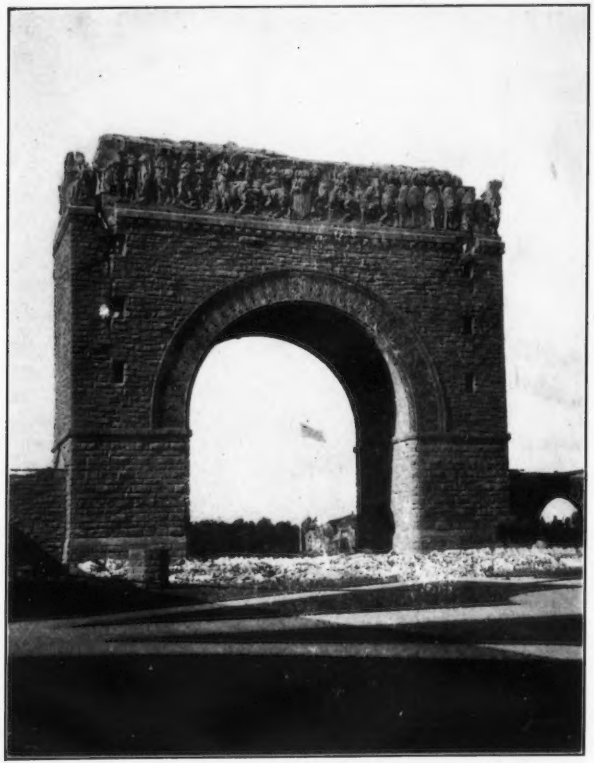


FIG. 1.—EARTHQUAKE DAMAGE TO MEMORIAL ARCH, STANFORD UNIVERSITY.



FIG. 2.—EARTHQUAKE DAMAGE TO BRICK ARCHES AND PARTITIONS, STANFORD UNIVERSITY.

the destructive movements, and, by reason of its amplitude, was not recorded by instruments. It is evident that the movement of a rock mass many miles in length, slipping for 10 or 20 ft. along a great fracture, would cause violent tremors to pass through the earth for many miles, diminishing in intensity as they traveled away from the fault line. It must also be apparent that such a movement may be followed by a series of minor movements and adjustments of the fractured zone, each causing its smaller earthquake, and that these might be expected to last for weeks or months and to diminish in intensity and frequency until a state of relative equilibrium was again established. The past history of earthquakes records this decreasing scale of intensity of shocks, and, while it may not be laid down as an exact law, the experience has been so general that it may be accepted as one, within certain limits.

An examination of the relief map of California, Fig. 1, Plate XVII, reveals the fact that the State is traversed by many important valleys having axes which are approximately parallel. As might be expected, geological study shows these to be fault valleys, the troughs of which are originally due to fracture and displacement of the earth's crust, rather than to the cutting action of streams. The entire western coastal region of the continent is characterized by these fault lines. They are directly responsible for the number of earthquakes in these localities, in that they give way and relieve the stresses in the earth's crust. Earthquakes, therefore, are frequent, but in the main not intense. It is certainly open to question if such a region is not preferable to those that have no such safety valve, and whose disturbances, while rare, may be too intense to be provided against successfully. Destructive earthquakes of greater intensity have certainly occurred in other parts of the United States, less populous, and without the publicity given by an unprecedented fire.

The San Andreas-Stevens Creek fault line, along which the movement took place in this instance, has been indicated by a line on the relief map (Fig. 1, Plate XVII), and also upon the map, Fig. 1. The directions of the relative lateral movement are shown by the arrows. The vertical movement, if any occurred, was slight. The geological section, *AB*, Fig. 2, shows in a general way the geological structure along a section through the Coast Ranges and Santa Clara Valley near San José, indicated and lettered *AB* on Fig. 1. The fault line crosses the section at Stevens Creek. It will be noted that San José stands upon a deep alluvial deposit, in which borings 1100 ft. deep have not encountered bed-rock. The unstable character of these deposits is doubtless responsible for the unusual extent of the damage done by the earthquake in San José.

The section shown is somewhat typical of the structure adjacent to the fault line throughout the region south of San Francisco. There are fault lines also on either side of the Stevens Creek fault, but, as far as known, no movement recently occurred along them. The fault line indicated on the eastern side of the valley, however, is probably one along which movement occurred in 1868 when a shock of some importance, but lacking much of being equal in intensity to that of April 18th, did some damage.

The fault block lying between the fault along the eastern side of Santa Clara Valley and the San Andreas-Stevens Creek fault has undergone a series of movements since Miocene time, as a part of the geologically active Coast Ranges. It has also experienced an uplift on the western side, with a coincident downthrow on the eastern side, at some time since the Pliocene, as is evidenced in this section by the up-tilted Pliocene gravels making up the hillsides on the west side of the Santa Clara Valley. The San Andreas-Stevens Creek fault line has been subjected to even more recent movements; it was therefore poorly cemented, and was the first to give way under the accumulating strain.

Map A (Fig. 1) shows the location of the fault line from Bodega Head to a point in the Coast Ranges west of San José. The region near Olema, shown on this portion of the fault line, is believed to have sustained the greatest movement. The greatest damage done was adjacent to the portion of the fault line within the limits of this map. The rift has been traced in detail from near Point Arena, in Mendocino County, on the north, to near San Juan, in San Benito County, on the south—about 185 miles. Topographic features and scattering reports of fractures observed indicate that the fault line probably extends beyond these limits, both northward and southward, and further investigation may develop connected evidences of movement on these extensions. However this may be, the already well-defined rift is of sufficient length to indicate a profound fracture which must extend to great depths below the earth's crust.

It will be noted on the accompanying maps that the line of the fault is characterized by a series of long, narrow valleys, comparatively straight sections of creek beds, and saddles in mountain ridges. The scarps, sink holes and troughs peculiar to fault lines along which recent movements (geologically speaking) have occurred are all in evidence along this line, and had been recognized and studied in some detail by the geologists of the California universities. After the earthquake, a movement was at once suspected along this well-known line, and subsequent investigation resulted in a verification of the work of location previously made. The exact location of the line of fracture is made evident by a

SKELETON MAP OF A PORTION OF ZONE OF
CALIFORNIA EARTHQUAKE OF APRIL 18TH, 1906.
Showing topographic features along fault line.

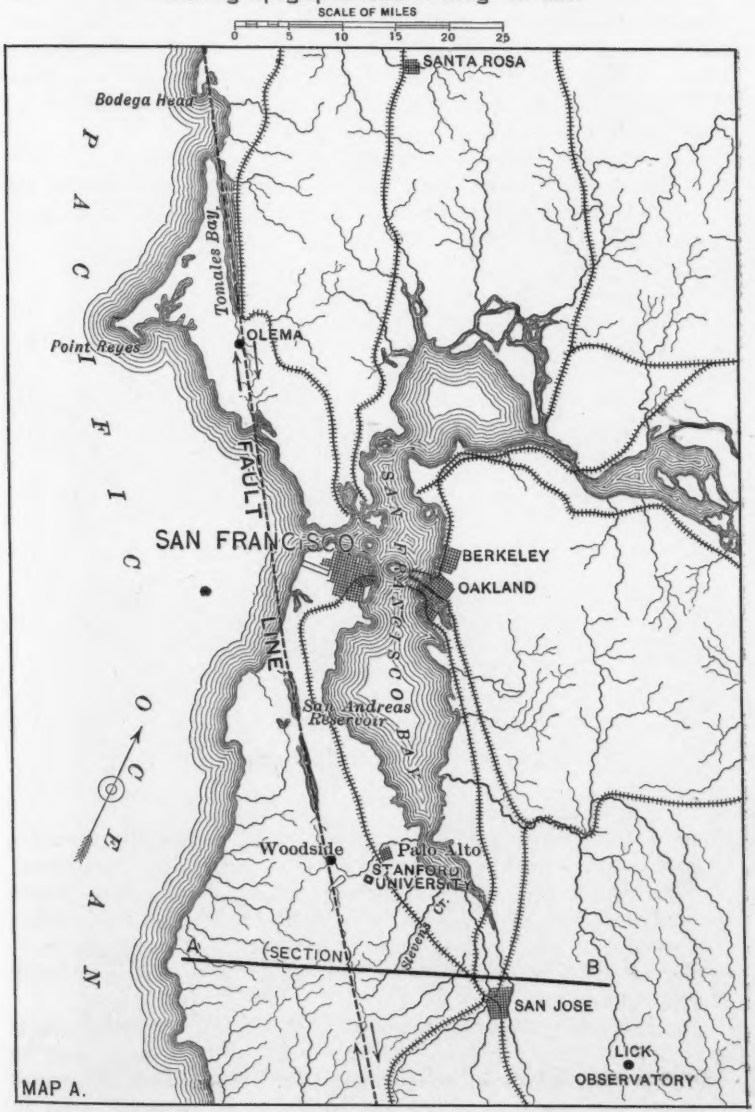


FIG. 1.

furrow several feet in width across the open fields and bare hills. The furrow takes on the nature of plowed ground, with occasional cracks, both longitudinal and transverse, and is remarkably straight. Through the forests the line is traceable by trees uprooted, shattered, or leaning. Everywhere, roads, fences and conduits are offset or telescoped. The accompanying photographs on Plates XVII and XVIII, give some indication of the character of the fault line phenomena.

In conclusion, it may be stated:

That the California earthquake of April 18th was due to the relief of accumulating stresses in the earth's crust, by a movement

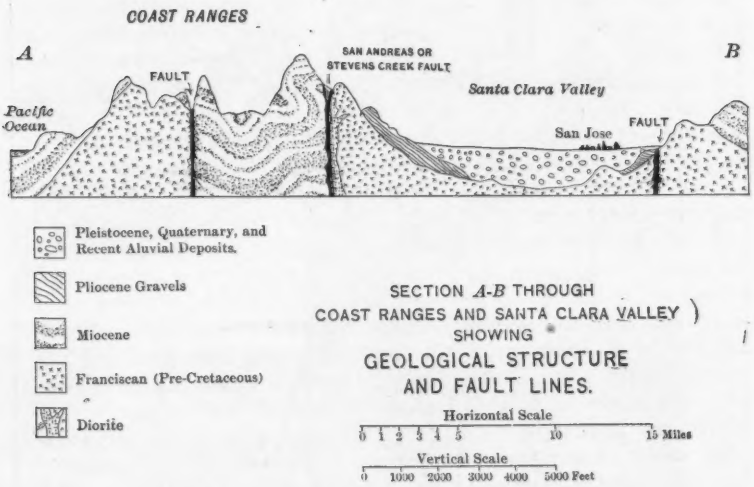


FIG. 2.

along a previously known fault-plane whose fracture, by reason of geologically recent movement, offered a line of least resistance;

That, while the time of occurrence of such movements cannot be predicted, the relief of the accumulated stresses gives reasonable assurance of freedom from a recurrence of earthquakes of similar intensity, within the area affected, for some time—probably at least fifty years;

That, by reason of the existence of this and many other fault-lines in California, through the agency of which stresses may be relieved when they reach the danger-point, earthquakes of greater intensity than the recent one are hardly to be expected, even in the remote future;

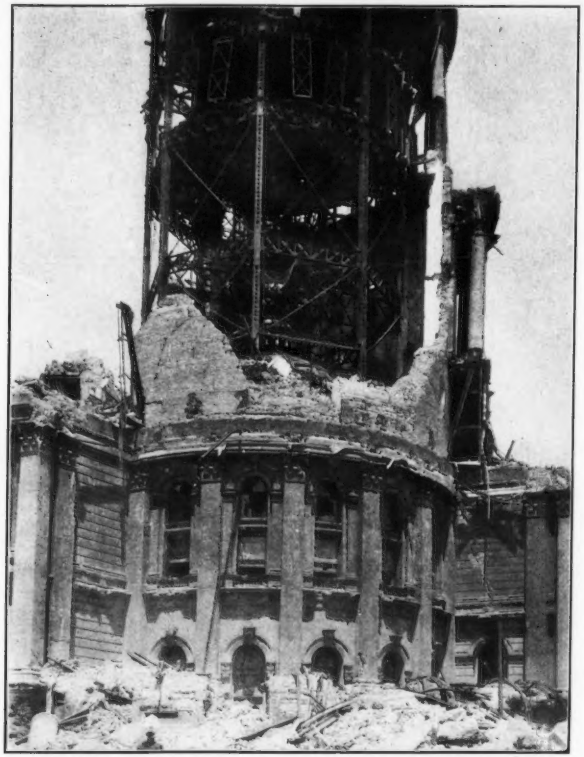


FIG. 1.—EARTHQUAKE DAMAGE TO CITY HALL, SAN FRANCISCO. NOTE THAT STEEL FRAME DID NOT SUPPORT THE WALLS.

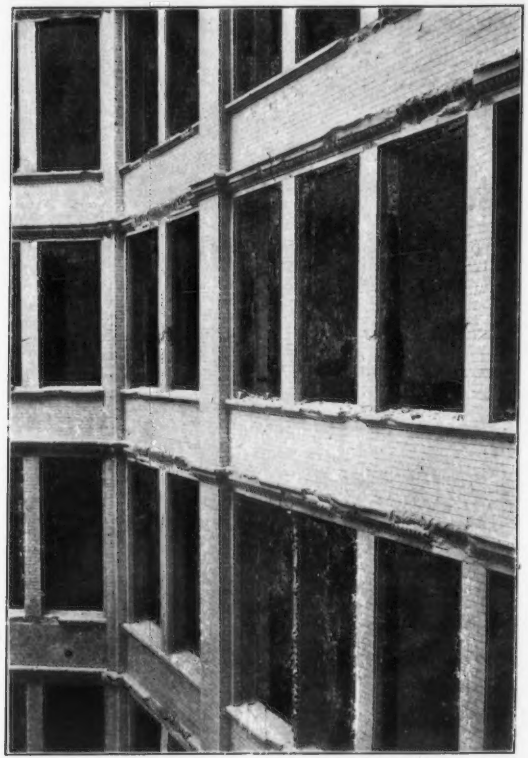


FIG. 2.—BREAKING OF TERRA COTTA BELT COURSES AND SILLS IN JAMES FLOOD BUILDING.

That the disastrous results following the recent earthquake, both as to loss of life and property, were largely due to a lack of safe construction, as ordinarily understood; and, if the lessons which may be drawn from it are followed in the future, it is believed that the Pacific Coast can be made safe as a habitation and field of investment, as far as earthquakes may affect conditions.

APPENDIX B.

REPORT OF COMMITTEE ON FIRE AND EARTHQUAKE DAMAGE TO BUILDINGS.

COMMITTEE:
J. D. GALLOWAY, M. C. COUCHOT, C. H. SNYDER,
CHARLES DERLETH, JR., C. B. WING.

The earthquake in the western portion of California, and the resulting fires in San Francisco and Santa Rosa on April 18th, 1906, caused a general destruction of engineering structures which is of interest to many engineers.

It may be stated that this report has been delayed in order that as complete data as possible might be obtained. The damage by fire and earthquake was extensive; and, in the case of fire damage, the effect on concealed parts was hidden, and could only be ascertained when the buildings were stripped. This can hardly be said to be complete as yet, but it was felt that the report could not be delayed any longer for that reason.

Some members of the committee have been employed in a professional capacity in the examination of damaged buildings. These statements, when considered in connection with the press of business in an extraordinary period, must be taken as the excuse for not furnishing to the profession an earlier report.

The region affected by the destructive effects of the shock was some 300 miles long by 50 miles broad, and covered the most populous part of the State, including the cities of Santa Cruz, San José, Alameda, Oakland, Berkeley, San Francisco, Napa and Santa Rosa, besides a number of smaller towns. No attempt is made here to enter into a detailed study of the shock, or its cause, such topics being treated by the Committee on Geology.

The shock was followed by destructive fires in San Francisco and Santa Rosa, which destroyed the entire business districts of both places. The area burned over in San Francisco slightly exceeded 4 sq. miles. Santa Rosa had a population of about 8 000, and its entire business district was burned. A number of institutions, such as Stanford University at Palo Alto, the State Hospital for the Insane at Agnews, and St. Patrick's Academy at Menlo Park, were badly wrecked.

No statistics are at hand as to the number of people killed, but it might reach 750. At Agnews' Asylum 112 people were killed, of whom more than 100 were patients.

PLATE XXIII.
PAPERS, AM. SOC. C. E.
MARCH, 1907.
REPORTS OF COMMITTEES ON
SAN FRANCISCO EARTHQUAKE.

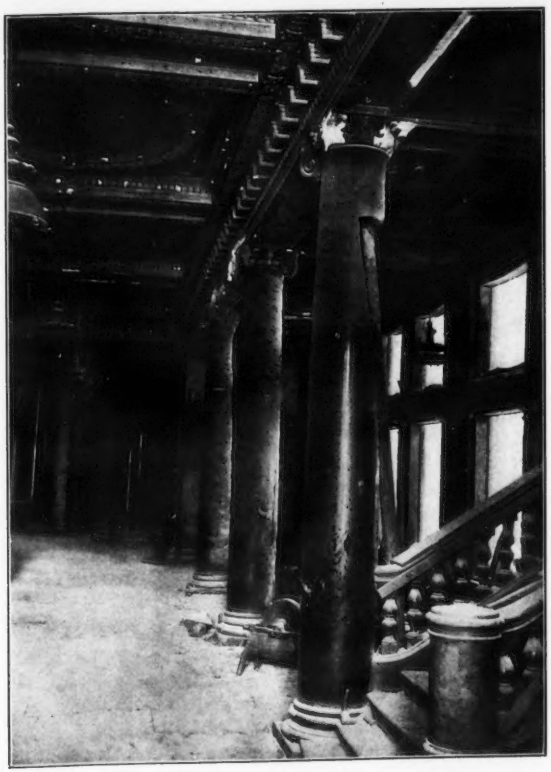


FIG. 1.—FIRE DAMAGE TO INTERIOR GRANITE COLUMNS IN JAMES FLOOD BUILDING



FIG. 2.—FIRE DAMAGE TO MARBLE STAIRWAY IN MILLS BUILDING.

It is not believed possible to locate any particular place as the center of disturbance, the effects being about the same in all parts of the area named. The character of the ground had considerable to do with the destructive effects, buildings on rocky hills suffering much less than those on alluvial plains.

Any consideration of the damage to buildings must be preceded by a description of the type of buildings; hence this report is naturally divided into three parts, namely:

I.—Description of Buildings;
II.—The Earthquake Damage;
III.—The Fire Damage.

I.—Description of Buildings.

For the purposes of this report, buildings are divided into five types, as follows:

Type 1.—Wood frame structures;
Type 2.—Structures with brick, stone or concrete block walls and timber floors and partitions;
Type 3.—Structures with brick and stone bearing walls, metal interior frames, and fire-proof floors;
Type 4.—Structures with steel frames supporting all wall and floor loads;
Type 5.—Reinforced concrete structures.

It must be recognized, of course, that there were various combinations of these types, but the classification is sufficiently definite for present purposes. Types 3 and 4 are nearly the same, but both fire and earthquake damage differed considerably in the two.

Building methods were about the same as in other parts of the United States, and hence a brief description is deemed sufficient. It must also be recognized that here, as elsewhere, there was much difference in structures placed under the same heading, the well-braced steel-frame building standing next to one without any attempt to supply bracing of any kind. For obvious reasons, no special building can be designated as being thus defective.

Type 1.—Wood Frame Structures.—With a few exceptions, all residences, including 2-story and 3-story flats, in the territory named, were of timber. The San Francisco ordinance allowed them to be built 45 ft. high. Some higher buildings existed in San Francisco, but no data are at hand regarding earthquake damage, as they were burned. The construction was generally with studding one story in height, the succeeding story studding resting upon the floor joists. Some balloon framing was used, but it was not general. This type included residences, and, in some small towns

and outside the fire limits in the larger towns, many store buildings were built in this way.

Type 2.—Masonry Walls, Timber Floors and Partitions.—This type of structure formed the more pretentious buildings of the cities and towns outside of San Francisco, and also the buildings at Stanford University, Agnews' Asylum, St. Patrick's Academy, and County Court Houses. In San Francisco, the great majority of business blocks were of this type, as were also the large private hotels and apartment houses. Under the San Francisco building ordinance, they could be built 100 ft. high, or 8 stories. Buildings of 2 or 3 stories might have, with the brick walls, a system of timber columns and girders, or a partition of timber studding, carrying the floors and roof. In higher buildings, cast-iron or steel columns and steel girders were used to support the joists. Roofs were of timber framing, covered with tin, or tar and gravel.

The Stanford University buildings had walls of brick with a facing of sandstone, one general type ruling throughout. Some of the older buildings had full stone walls, and these were but slightly injured. They were built by various architects. In some, wooden roofs without trusses were used; in others, steel or wooden trusses; and this feature had a marked effect in determining the amount of damage.

The Palace Hotel, an 8-story structure, occupying a large lot, was of this type, honeycombed with interior partitions of solid brick walls, tied together with numerous iron anchors. This building withstood the shock well, but a similarly constructed building at Agnews' Asylum was completely wrecked. Buildings with hollow-block walls were few in number; one of 4 stories in Oakland, one at San José, and four of 2 stories at Palo Alto, are all that have been noted, although others may exist.

Type 3.—Masonry Walls, Metal Interior Frames, and Fire-Proof Floors.—A list of the buildings of this type in San Francisco, with details of construction, is given in Table 1.

Outside of San Francisco, this type was not used, except for some County Court Houses. The older fire-proof buildings were of this type. Generally, the walls were self-supporting only, columns carrying all floor loads. This applies to buildings of 8, 9, and 10 stories. In buildings of less height, generally, the floor load next to the wall was carried by the wall. Data of the construction are given in Table 1. Very little attempt at bracing was used in this type, the Crocker Building offering the only instance of systematic design, and that not being very effective. All had fire-proof floors and partitions.

Type 4.—Structures with a Steel Frame Supporting all Wall and Floor Loads.—A list of these structures in San Francisco, with

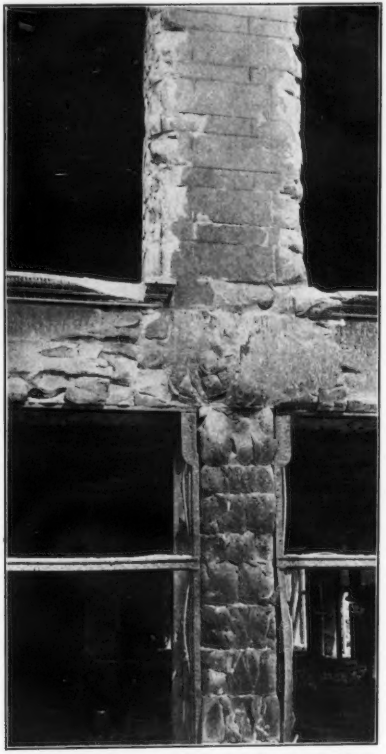


FIG. 1.—SPALLING OF MARBLE FRONT BY FIRE.

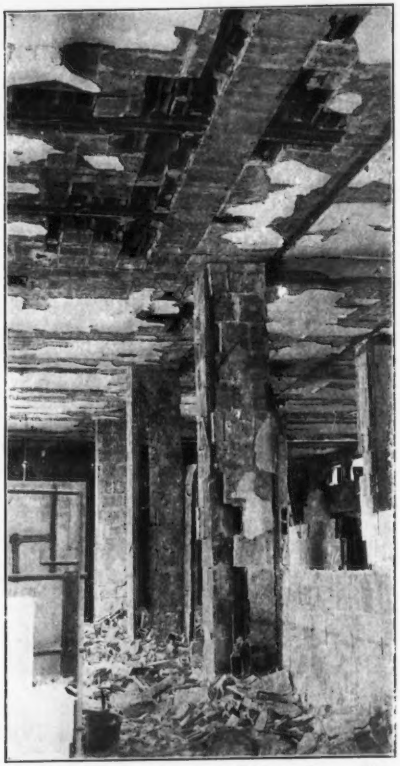


FIG. 2.—FIRE DAMAGE TO TERRA COTTA TILE PARTITIONS AND COLUMN FIRE-PROOFING.

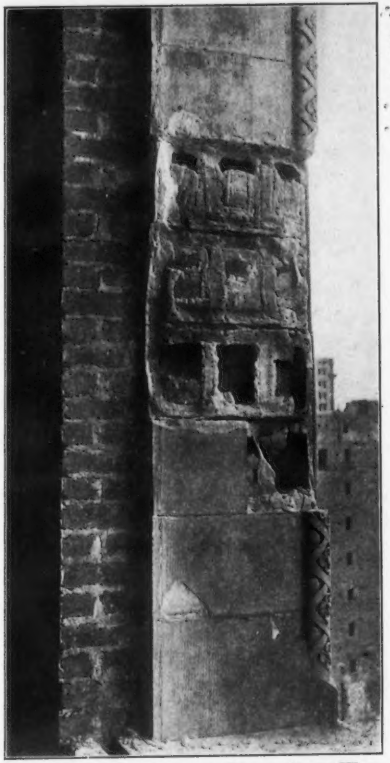


FIG. 3.—FIRE DAMAGE TO TERRA COTTA WINDOW TRIM. A GOOD EXAMPLE OF AVERAGE DAMAGE TO TERRA COTTA AROUND WINDOWS.

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TABLE 1.—BUILDINGS OF TYPE 3 IN SAN FRANCISCO.

Name of Building.	Stories.	Approximate area.	Use.	Front Walls.		Columns.	Floors.	Ceilings.	Column protection.	Partitions.
				Lower.	Upper.					
Academy of Sciences.	6	7 500	Museum Offices.	G.	S. S.	Cast-Iron.	Concrete.	None.	Metal Lath.	Metal Lath.
California Casket....	7	10 700	Under constr'n.	S. S.	S. S.	Channels.	"	"	Concrete.	None.
City Hall.....	.....	.....	.....	B.	B.	.....	Misc.	Misc.	.....	.....
Crocker	11	10 000	Offices.	G.	B. & T. C.	Phœnix.	Tile.	Tile.	T. C.	T. C.
Crocker Estate.....	5	.....	Lofts.	T. C.	B. & T. C.	Cast-Iron.	Concrete.	None.	None.	None.
Emporium.....	6	.....	Store. Offices.	S. S.	S. S.	Z-Bars.	Tile.	Tile.	T. C.	T. C. and Plaster Bl.
Ferry Building.....	3	112 000	.....	S. S.	S. S.	Cast-Iron.	Concrete.	None.	None.	B.
Hall of Justice.....	5	.....	Offices.	S. S.	B.	Pl. and Angles.	"	Metal Lath.	Metal Lath.	Metal Lath.
Hibernia Bank	2	17 000	.....	G.	G.	....	"	" "	.....	.....
Kamm.....	7	9 000	Lofts.	S. S.	S. S.	Channels.	"	None.	Metal Lath.	Metal Lath.
Majestic Theatre.....	.....	.....	.....	B.	B.	.....	Tile.	Metal Lath.	.....	.....
Mercantile Trust.....	3	5 500	.....	G.	G.	.....	Concrete.	" "	.....	.....
Mills.....	11	21 000	Offices.	M.	B. & T. C.	Z-Bars.	Tile.	Tile.	T. C.	T. C.
Mutual Life	9	5 000	"	G.	B. & T. C.	"	"	"	T. C.	T. C.
Old Chronicle	9	.....	"	S. S.	B.	Cast-Iron.	"	"	T. C.	T. C.
Post Office.....	3	68 000	.....	G.	G.	Channels.	Concrete.	Metal Lath.	.....	.....
Scott.....	6	20 000	Lofts.	S. S.	S. S.	Cast-Iron.	"	None.	None.	None.
Sloan	6	.....	.....	T. C.	B. & T. C.	"	"	"	Metal Lath.	"
Spring Valley	6	19 000	Offices.	G.	B. & T. C.	Z-Bars.	Tile.	Tile.	T. C.	T. C.
Union Trust.....	9	8 400	"	G.	B. & T. C.	Channel.	"	"	T. C.	T. C.
Wells Fargo.....	6	19 000	"	G.	B.	Cast-Iron.	Concrete.	Metal Lath.	Double M. L.	Metal Lath.
Young.....	6	3 000	Lofts.	G.	B.	Z-Bars.	"	None.	Metal Lath.	None.

Abbreviations:—S. S. = Sandstone; G. = Granite; T. C. = Terra Cotta; B. = Brick; M. = Marble.

TABLE 2.—BUILDINGS OF TYPE 4 IN SAN FRANCISCO.

Name of building.	Stories.	Approximate area.	Use.	Front Walls.		Columns.	Floors.	Ceilings.	Column protection.	Partitions.
				Lower.	Upper.					
Alexander Hotel	11	4 700	Hotel.	S. S.	S. S.	Channels.	Concrete.	Metal Lath.	Metal Lath.	Metal Lath.
Alto	8	1 500	Offices.	B.	B.	"	"	" "	" "	" "
Aronson	10	9 350	Lofts.	S. S.	B. & T. C.	"	"	None.	T. C.	T. C.
Atlas	10	2 700	Offices.	B.	B.	"	"	Metal Lath.	Metal Lath.	Metal Lath.
Bullock and Jones	8	4 000	Lofts.	T. C.	T. C	"	"	None.	T. C.	" "
Claus Spreckels	19	5 600	Offices.	S. S.	S. S.	Z-Bars.	"	Metal Lath.	T. C.	T. C.
Fairmount Hotel	6	66 000	Under constr'n.	G.	T. C.	Channel.	"	" "	Metal Lath.	Metal Lath.
Grant	8	5 500	Offices.	T. C.	T. C.	"	"	" "	T. C.	T. C.
Hamilton Hotel	12	3 100	Hotel.	S. S.	S. S.	"	"	" "	Metal Lath.	Metal Lath.
James Flood	11	40 000	Offices.	S. S.	S. S.	Z-Bars.	Tile.	" "	B. & T. C.	T. C.
Kohl	11	9 000	"	S. S.	S. S.	Channels.	Concrete.	" "	Metal Lath.	Metal Lath.
Marston	8	1 200	Under constr'n.	B. & T. C.	B. & T. C.	"	"	.....	Concrete.	.....
Merchants Exchange.	14	25 000	Offices.	G.	B.	Pl. and Angles.	"	Metal Lath.	Metal Lath.	Metal Lath.
Monadnock	10	18 000	"	B.	B.	Channels.	"	" "	" "	" "
Mutual Savings Bank.	12	5 000	"	S. S	S. S.	Z-Bars.	"	" "	" "	" "
New Chronicle	16	5 600	Under constr'n.	B.	B.	Pl. and Angles.	Tile.	Tile.	T. C.	T. C.
Rialto	9	16 000	Offices.	T. C.	B. & T. C.	Channels.	Concrete.	Metal Lath.	Metal Lath.	T. C.
Ruef	8	1 000	Under constr'n.	.....	.....	"	"	.....	.....	.....
Shreve	11	9 000	Offices.	S. S.	S. S.	Z-Bars.	"	Metal Lath.	Concrete and T. C.	T. C.
St. Francis Hotel	14	22 000	Hotel.	S. S.	S. S.	"	"	" "	Concrete and T. C.	T. C.
Telephone Co	8	2 500	Offices.	B.	B.	Channels.	"	" "	Metal Lath.	Metal Lath.

Abbreviations: — S.S. = Sandstone; G. = Granite; T. C. = Terra Cotta: B. = Brick; M. = Marble.



FIG. 1.—FIRE DAMAGE TO TERRA COTTA ORNAMENT. NOTE GOOD CONDITION OF MOULDED BRICK.

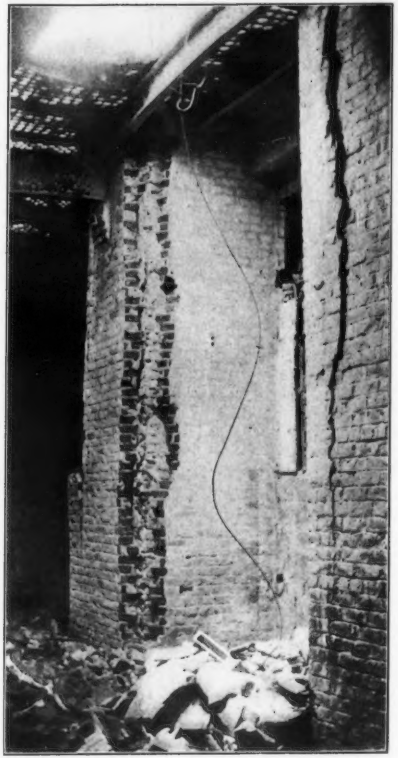


FIG. 2.—SPALLING OF CORNER BRICK PIERS IN BASEMENT OF MILLS BUILDING.

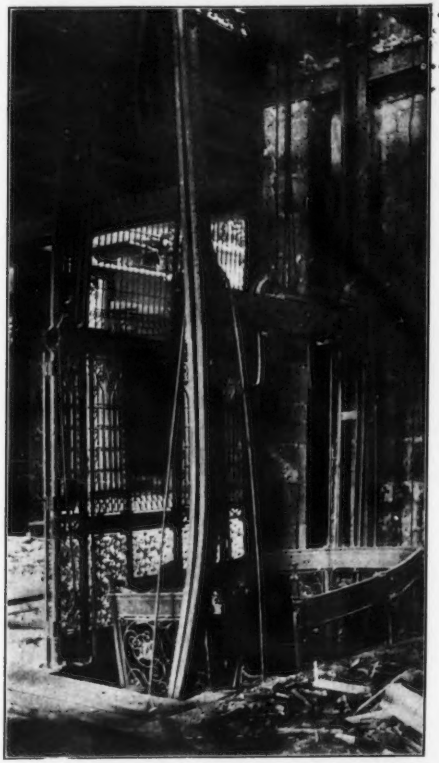


FIG 3.—FIRE DAMAGE TO ELEVATOR APPLIANCES IN MILLS BUILDING.

details of construction, is given in Table 2. Outside of San Francisco, there were but few, one in Berkeley, of 7 stories; two in Oakland, the highest having 11 stories; one in San José under construction (steel frame up); and the Spreckels Sugar Refinery near Salinas, of 5 stories. All were built with fire-proof floors and brick walls, with brick, stone, or terra cotta fronts. The frame was of steel in all cases noted.

Type 5.—Reinforced Concrete Structures.—Only a few structures of this type existed in the territory affected, and these were built a number of years ago. The old portion of the Museum, and Roble Hall, at Stanford University, were built after the Ransome system but little reinforcement was used in the walls. In Alameda there was a 4-story factory building built on the same system. At Redwood City there was a small 2-story sub-station, and in San Francisco a building was in course of construction with reinforced concrete columns and floors, but with brick walls. The Academy of Sciences had a complete reinforced concrete floor system on cast-iron columns. There was a 1-story factory in Berkeley, and a 3-story factory near Vallejo; also, two residences in country towns. As far as known, these nine instances are all there were in the earthquake region.

II.—The Earthquake Damage.

It is probable that the subject of earthquake damage will be of less interest than that of the fire damage. While considerable that has been learned can only be applied in earthquake centers, still there are many interesting points applicable to other regions. Again, while it is admitted that the Pacific Coast of the American Continents is subject to earthquakes, they are by no means limited to that region. The Charleston earthquake or the one early in the last century in the Mississippi Valley, while not as severe as that in California, might have been sufficient to destroy water supplies and start fires in any large city, the effect of which might have been as destructive as at San Francisco or as at Valparaiso.

Authorities are agreed that ground vibrated by an earthquake has both a vertical and a horizontal motion. The amount has been stated as 1 in. and 3 in., respectively, in the shock under consideration. The amount of motion undoubtedly varies, depending upon the character of the ground. Filled lands and alluvial plains undoubtedly have more motion than rocky hills. By these two motions and their combinations, a building may be damaged in two ways. If large in plan, one portion may be lifted and dropped before the remaining part moves, thus distorting the frame. In either case, a swaying motion is set up, the effect of which is more or less destructive, depending upon the elasticity of the structure, the same stresses occurring as when a live load passes over a truss.

The damage to buildings by the earthquake can now be taken up by considering each type as designated in Part I.

Type 1.— Wood Frame Structures.—The principal damage to buildings of this type was the cracking of plaster and the wrecking of brick chimneys, which occurred everywhere. Numbers of houses were distorted and damaged, by the movement of filled ground upon which they stood, enough to compel their being taken down. This ground vibrated much more than other kinds, and resulted in upsetting houses. Numbers of houses with rotten foundations were upset, and in some cases 3-story structures lurched forward, breaking at the second-floor level and collapsing the first story.

Speaking generally, there was little damage to wooden frame buildings. Undoubtedly, they should be well braced, and the foundation should be carried below the soil to a firm material. Mention might be made of the precaution that pictures and other ornaments in sleeping apartments should not be placed so that in falling they may injure the sleepers. The greatest source of danger lies in brick chimneys. Innumerable instances occurred where the chimney broke through the roof. It may seem paradoxical to say that if brick chimneys must be used, they should be built with poor mortar above the roof line, but the reason is that, if so built, they will be shattered and will fall in parts. If well built, and falling as a whole, the effect is much more destructive. It is idle to expect the exposed portion of a chimney of ordinary dimensions, even of brick and Portland cement, to stand, when vibrating with a house during an earthquake. Some statements are added in the general conclusions following.

Type 2.—Masonry Walls and Timber Interior.—Buildings of this type suffered most from the shock, and in them the greatest loss of life occurred. The damage ranged from minor cracks in brickwork to the complete destruction of large buildings. The swaying motion produced by the earthquake caused diagonal cracking in all directions. In all structures with brick, coursed-stone, or concrete-block walls, these diagonal cracks appeared, crossing each other and generally running at about 45° with the horizontal. Piers between windows, spandrels between window heads and sills, and interior partitions were thus affected. Stone mullions, sills, and transoms were cracked, and large sandstone and granite blocks were split.

Another feature was the shearing of brick walls near the ground. Walls of any length would be sheared from a just-to-be-seen crack up to an amount that upset the entire wall by removing the support.

Gables were upset everywhere. As built, there was little if any connection between the wooden roof and the brick. As the

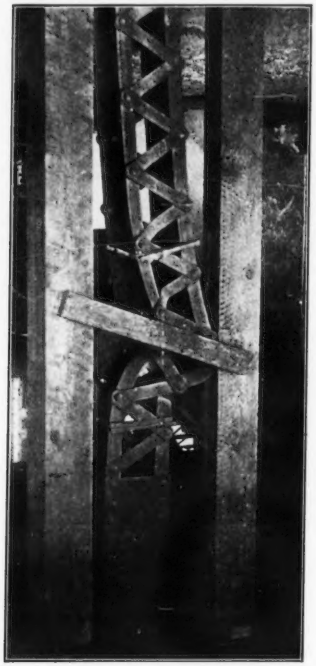


FIG. 1.—BUCKLED COLUMN IN FAIRMOUNT HOTEL.



FIG. 2.—BUCKLED COLUMN IN BASEMENT OF ARONSON BUILDING.



FIG. 3.—BUCKLED COLUMN IN MILLS BUILDING. TERRA COTTA TILE PROTECTION.



FIG. 4.—FIRE DAMAGE TO PHŒNIX COLUMN IN CROCKER BUILDING.

wall was thin, it resulted in upsetting the gable. The most marked instance of this was the gable wall of the Memorial Church at Stanford University, which stood, practically disconnected from the wooden roof. It was ornamented with a costly mosaic, and the entire wall fell.

Buildings of this type also suffered by the wrecking of fire-walls and cornices, which, falling in or out, did much damage. Some fire-walls, falling on lower buildings, wrecked them. People were killed in the street by cornices and upper walls falling outward.

A favorite method of constructing such buildings, when used as stores, was to build the front wall upon a girder, placed at the second-floor level, and supported on columns. As the interior frame was generally independent of this girder and the wall, the result was that the wall fell outward.

Another cause of the destruction or partial wrecking of such buildings was the roof construction. Cases were observed where roofs, of as much as 80 ft. span, were built with inclined rafters resting upon the walls and unprovided with horizontal ties of any kind. When the building was in motion, the inclined rafters acted as thrust pieces to overturn the walls.

The foundations of such buildings were generally found intact, the damage increasing toward the top. Many arches were opened at the crown, and the arch stones or bricks dropped.

It must be recognized that buildings of this type were general throughout the region of the shock. The damage ranged from slight cracks to the complete destruction of large structures, hence no general statement covers the case. A few individual statements may be of interest. In Oakland, a concrete-block building, 4 stories high, was injured little if any. At Palo Alto, two such structures, 2 stories high, probably not very well built, were completely wrecked, the blocks being broken and disintegrated.

At the Agnews' State Asylum, large 4-story structures were completely wrecked. The walls stand, but are shattered everywhere. At this place, all partition and hall walls were brick, the buildings being a series of cells. It is difficult to describe the destruction of this brickwork. Probably 90% of the mortar bonds were broken, leaving the wall but a pile of loose bricks. The mortar was of fair grade. A large tower of brick over one building fell, doing much damage. At San José, the large City Hall, of brick, with brick partition and hall walls, was shattered everywhere. The old County Court House was not badly hurt, but two later buildings were badly shattered.

At Stanford University, the uniform method of construction was brick walls, with a veneer of coursed ashlar. The buildings

were connected by numerous arcades formed with two rows of arches covered by a hip roof. The arches rested upon single stone columns. Several buildings here were completely destroyed, notably the large Library, Gymnasium and Museum buildings. The arches were injured by the dropping of keystones, the movement of supporting columns and the falling of spandrels. In many of the walls there was a separation of the ashlar facing from the brick backing. The cracking of walls, with other damage as noted above, was evident everywhere. Foundations were nowhere injured.

At St. Patrick's Academy, at Menlo Park, some large 4-story brick buildings were damaged, the worst effect being in the two upper stories. Two-story structures were but little injured. A tall tower on one building was badly wrecked.

At Santa Rosa, nearly every brick building was wrecked, and the resulting fire destroyed the entire business part of the town.

In San Francisco, while there are some special instances of buildings of this class withstanding the shock, there are others where there was complete destruction. The Palace Hotel is a notable instance of how a brick building may withstand the earthquake, it being practically uninjured.

Type 3.—Masonry Bearing Walls, Metal Interior Frames and Fire-Proof Floors and Partitions.—It may be questioned why this type was separated from Type 4, with a steel frame carrying all loads. The reason is that buildings of this type were damaged more by earthquake and fire than those of Type 4. In Table 1, showing the buildings of this type, no distinction is made between walls carrying some of the floor loads and those where all floor loads were carried on a steel frame—columns being placed in the walls. Of the latter class, the Mills, Crocker, Kamm, Union Trust and Mutual Life Buildings are examples. The frame of the Mills Building (1891) has columns of one-story section, each section resting upon the cap of the one below, and connected thereto with four bolts. Beams and girders rest upon the cap plate, and the entire structure was bolted above the third floor. After the earthquake and fire, this building leaned from 7 to 9 in. out into Bush Street. The distortion of the frame was uniform above the second floor. There being no crack in the outer walls, it is difficult to say whether this movement was due to the shock, or had been a gradual movement from the time of construction. As all buildings of this type were burned, it is difficult to separate earthquake from fire damage.

In the Kamm Building, one wall, 7 stories high—60 ft. of 13-in. wall and the remainder 17-in.—sprung out about 14 in. near the middle height. The reason is obscure, some stating that it was caused by the explosion of dynamite. In other respects, the outer

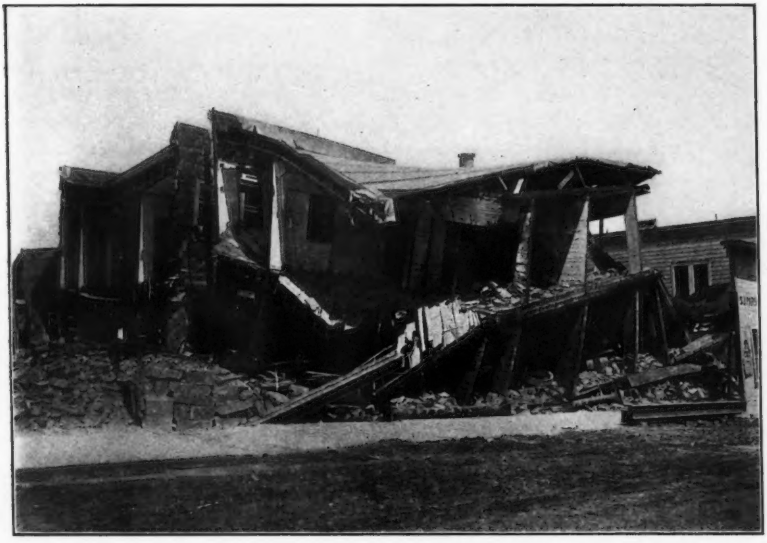


FIG. 1.—CONCRETE BLOCK CONSTRUCTION IN PALO ALTO, DAMAGED BY EARTHQUAKE.



FIG. 2.—FIRE DAMAGE TO INNER COURT OF MILLS BUILDING.

walls of buildings of this type suffered as other brick walls. Interior partitions of terra cotta show all the characteristic cracks of brick walls, the mortar joints being broken and opened from ¼ in. to 2 in. Cornices, being generally supported on iron brackets, held, but here, also, it is difficult to separate fire from earthquake damage. Speaking generally, those buildings with a steel wall column supporting the floors suffered less than those where the walls held the floors.

Type 4.—Structures with a Steel Frame Supporting all Wall and Floor Loads.—Relatively, buildings of this type were those most exposed to earthquake damage, the type including most of the tall buildings in the city. Here, as elsewhere, it was a question of bracing. Some frames were well braced, others partially so, others not at all. The Claus Spreckels Building (19 stories), about 80 ft. square in plan, was braced better than any. Portal bracing was placed on each side of each corner, up to the third floor. In addition, there were eight lines of eye-bar diagonals from the basement to the fourteenth floor and three above. All girders had gusset-plate knee-braces. The Mutual Savings Bank Building (12 stories) had two lines of portals and two lines of eye-bar diagonals from top to bottom. The New Chronicle (16 stories) had deep girders and gusset-plate knee-braces throughout. The Shreve Building (11 stories) had deep girders and two complete systems of portal bracing. The Kohl Building had deep lattice girders throughout. The Merchants' Exchange, St. Francis Hotel, Fairmount Hotel, Monadnock, Rialto, and James Flood Buildings were large in area, and were without special wind bracing.

Earthquake damage consisted in cracks in partitions, where made of tile. On the buildings where corner piers of stone rested upon concrete under the sidewalk, the stonework was badly cracked. Where such stone was carried on the steel frame, no cracks are found, but there are only a few instances of this method. Walls of brick, or of stone and brick, did not suffer as much as might have been expected. The rear walls of the St. Francis Hotel were cracked. The walls of the Atlas Building were affected in the same manner. The rear brick walls of the Merchants' Exchange moved outward on the girders from 1 to 3 in. On the Spreckels Sugar Refinery, near Watsonville, there were several cases of the 13-in. brick walls being thrown down, but no such damage occurred in San Francisco. A number of piers and spandrels of the brick front of the new Chronicle Building were cracked, as were also the terra cotta faces of the Fairmount. The brick front of the Monadnock was badly cracked. On the Claus Spreckels Building, the sandstone fronts were intact up to the tenth story. From there to the sixteenth story, the stonework was badly worked on the beds.

Some stones were split, and nearly every one moved, the maximum movement being possibly 2 in. This stonework rested on girders, and was backed with brick. The dome of the building containing the seventeenth, eighteenth and nineteenth floors, was covered with terra cotta, each piece being anchored to the metal frame. As far as could be determined, no damage or movement of this terra cotta took place. The same is true of the terra cotta gables of the Mutual Savings Bank. As far as observed, the damage to stone facing was greatest on the Claus Spreckels Building.

To the statement of damage to stonework, exception must be taken in the case of stone cornices. Elaborate cornices of sandstone were used on the Claus Spreckels, Mutual Savings Bank, Kohl and James Flood Buildings, all supported on iron brackets, and no movement or breaking of stone could be observed. The same is true of terra cotta cornices on other buildings; in fact, the care taken to support cornices seemed to protect them from damage.

No foundation damage was observed in any buildings.

The damage to steel frames was almost negligible. Some rivets were sheared in the James Flood Building, and in the Union Trust Building a number of bolts were sheared. As most of the frames are hidden, the extent of the damage is unknown, but is probably small. A few of the eye-bars of the diagonal bracing of the Claus Spreckels Building were bent, as if the opposite ones had taken the strain. A careful examination failed to reveal any sheared rivets. The greatest damage to a steel frame was that of the tower of the Ferry Depot. This tower was about 40 ft. square and some 200 ft. high above the main structure. It was sheathed with brick and stone, except the top, which was of metal. The frame had a column at each corner, with a complete system of diagonal rods. A number of rods were broken, and in places the gusset-plates were torn and the rivets sheared. This building rests upon piles driven into deep mud, and it was probably badly shaken.

Type 5.—Reinforced Concrete Structures.—Only a few instances of this type exist. The old portion of the Stanford University Museum, a complete structure, was uninjured, except for a few cracks. The connecting brick portion was badly shattered. Roble Hall, at the same place, a 3-story and attic structure, was uninjured, except where some brick chimneys fell, breaking the roofs and floors. The sub-station at Redwood City was injured, and a part had to be rebuilt. This structure was built on marshy ground near the bay, and was exposed to the worst effects of the shock. A warehouse in San Francisco, in course of construction, with two stories up, had its brick walls wrecked, but the reinforced concrete frame and floors were uninjured, except by the fall of the



FIG. 1.—UNITED STATES MINT, SAN FRANCISCO. WITHSTOOD EARTHQUAKE AND FIRE.



FIG. 2.—HALL OF JUSTICE, SAN FRANCISCO, AFTER EARTHQUAKE AND FIRE.

walls. The floors of the Academy of Sciences and of the Folger Building were uninjured by the shock, and the same is true of the complete reinforced concrete building, 3 stories high, in Alameda. The factory buildings and residences before mentioned were uninjured. These constitute the only examples of this type known to the writers, but all the evidence points to the superiority of this method of construction.

Conclusions.—The writers offer the following as conclusions based upon a study of the effects of the earthquake. These conclusions are offered for the reason that it is recognized to be impossible to set forth in a partial description a full idea of the damage.

The effect of the earth motion is to set a building in motion. The structure is thus subjected to all the stresses occurring in a truss sustaining a live load. The amounts of the stresses are unknown, and cannot be predicted, as the intensity of the shock is unknown. Obviously, the shock may range from a tremor to that of a violence that would wreck any building. Again, should the earth-slip take place beneath a building, it would be wrecked. Sufficient evidence is at hand to warrant the statement that a building designed with a proper system of bracing to withstand wind at a pressure of 30 lb. per sq. ft. will resist safely the stresses caused by a shock of an intensity equal to that of the recent earthquake in California.

The prime requisite of the structure is elasticity. This must be understood as the ability of a structure to return to its original form after distortion. This elasticity allows the building to absorb the motion of the earth, where a more rigid structure would be ruptured.

To this requirement, the building with a timber or steel frame answers very well. The reinforced concrete structure does so also, with the exceptions noted below. The building with stone, brick or block construction, having horizontal mortar joints, does not answer the requirement at all. It may be stated, as one of the most obvious lessons of the earthquake, that brick walls, or walls of brick faced with stone, when without an interior frame of steel, are hopelessly inadequate. As a method of building in earthquake countries, such types are completely discredited.

To resist the shearing effect of the horizontal earth motion, vertical members are necessary. The shear is transformed into diagonal forces, which appear as stresses in diagonal and horizontal members. There was probably no better illustrated lesson of the existence of diagonal stresses than that offered by the innumerable instances of the cracking of brick and stonework along diagonal lines. In relation to this, it may be stated that a brick spandrel wall adds little, if any, to the bracing of a steel frame.

Many of such walls were cracked badly, and moved on the supporting girder. No reliance should be placed upon them, as they are open to all the objections stated in connection with brick walls in general. The well-designed steel frame offers the best solution of the question of an earthquake-proof building, as all the stresses can be cared for. The well-designed timber-framed house is also adequate. A reinforced concrete building offers a solution, but is open to the following objections:

Architectural reasons demand that diagonal bracing shall not be used except on rare occasions. This is overcome by the use of gusset-plate knee-braces and portal-braces in the steel frame. Such design induces severe bending moments in the columns and girders; and, in the girders, the moment may be of the opposite character to that of the floor loads, thus producing tension in the upper flange of the girder. As at present designed, no reinforcement is used at that point, and hence such a girder would be defective. Again, it will be found upon analysis that relatively great stresses occur at points where the girders join the columns, especially in the lower floors of tall buildings. Here, again, the reinforced concrete construction, as now designed, is weak. These remarks are offered more in connection with high buildings. They can be overcome by the designer in reinforced concrete. All the evidence in the recent shock favors reinforced concrete, but the writers are of the opinion that the steel frame offers the best solution of the problem.

Foundations did not suffer at all, no instances of any damage having come to hand. Some discussion has taken place as to the advisability of making a monolithic mass under buildings. Several of these have been constructed, such as the Claus Spreckels, Mutual Savings Bank, and Bullock and Jones Buildings. They are all of relatively small base. It is commercially impossible to construct a monolithic base under a building, say, 12 stories high, and having a base of 150 ft. Buildings of that size and larger, with isolated pier foundations, suffered no more than others. The evidence is that foundations well built, along accepted lines, are adequate. It might be claimed that, if such had been used in large structures, the damage would have been less. The evidence does not point that way, for even if the monolithic base were sufficiently strong to resist the vertical earth motion, the horizontal motion would still vibrate the structure.

Evidence for floors is not conclusive, as all terra cotta arch floors were afterward burned. Terra cotta arches covered with concrete stood without much damage in the brick portion of the Stanford University Museum. The terra cotta there could not be seen. Analogy with masonry walls would seem to say that many



FIG. 1.—FIRE DAMAGE TO RESIDENCES AND HOTELS OF TYPE 2 CONSTRUCTION IN SAN FRANCISCO.



FIG. 2.—DESTRUCTION OF BUILDINGS OF TYPE 2 CONSTRUCTION AT FOOT OF MARKET STREET, SAN FRANCISCO.

Manoli

of the joints would be broken. Ordinary concrete floors stood the shock with but little damage.

In the case of partitions, those of terra cotta tiling were everywhere cracked and opened. It amounted to practical destruction in most cases. In this case, earthquake damage can be distinguished from fire damage. Partitions of metal studs and lath suffered less, but plaster was badly cracked. Nothing seems to be suggested for a partition, in which the plaster would not be destroyed.

For rear walls, reinforced concrete offers the best solution, the reinforcing members being tied to the steel frame. A facing of brick or stone could be backed with reinforced concrete. In the case of stone, the parts should be doweled together, and, if possible, all tied to the steel frame. Terra cotta as a facing for walls is admirable, in this respect, as it offers superior facilities for tying it to the steel frame. For fire and parapet walls, the steel frame should be carried up, and anchors should be provided.

Brick chimneys, large and small, are open to all the objections of brick walls, only in a more marked degree, owing to their isolated design. Reinforced concrete seems to offer the best method for such construction.

Arches with voussoirs are not able to resist earthquakes. The motion opens the joints, and the keystones fall, thus thrusting aside the abutments. Evidences of this exist everywhere.

Finally, it may be questioned whether difference in workmanship was not responsible for many of the results. While it is true that good workmanship gave better results than ordinary, it is still the opinion of the writers that it was mainly a question of design. Agnews' Asylum was of brick, laid in a fair grade of lime mortar. Ten miles away, on similar ground, St. Patrick's Academy, of similar design, was of brick, laid in lime and Portland cement, and there was better work than at Agnews'. The damage at the latter place was less than at the former, but, as far as use was concerned, both places were demolished. The tower at St. Patrick's Academy was of brick, laid entirely in Portland cement mortar, and the work was so well done that the brickwork invariably broke through the bricks and not at the joints; yet the tower was completely destroyed; in fact, it was the worst wrecked of all the buildings there.

The writers simply reiterate the statement that, speaking generally, buildings of brick walls and wooden interiors cannot be built which will not be wrecked in a severe shock, it being a fault of design and not of materials or workmanship.

III.—The Fire Damage.

Within half an hour after the earthquake shock, the Fire Department of San Francisco had notice of fifty-two different fires.

It is probable that others had started. The fire lasted three days, being finally stopped by dynamite, wide streets, and individual efforts. The wharves of the city were saved by State and United States Navy tugs. Only a portion of the residence district was saved. Some isolated fires were extinguished by the Fire Department, using water in the dead ends of mains. The destruction of the supply mains, described in another report, was complete, and hence the entire fire burned without interference. The area destroyed was a trifle in excess of 4 sq. miles. It was entirely covered with buildings, excepting where there were lumber yards. A few isolated blocks escaped, but they are of no interest in connection with this report.

In commenting upon the destruction by this fire, it must be borne in mind that no water was used on any of the materials. Hence, in some cases, the damage is less than it might have been had water reached the materials while they were hot.

Of the buildings within the burned area, estimated at nearly 20 000, only those given in Tables 1 and 2—some 50 or 60—remain standing. All others are completely destroyed, only some brick walls standing here and there. Unless one has been an eye-witness, it is difficult to realize how all materials that men make into the shape of buildings can be so utterly destroyed in a general conflagration. With two exceptions—the Kohl and Atlas Buildings—all the buildings in Tables 1 and 2 were completely burned in the interior, only the frame remaining.

All the business center of the City of Santa Rosa was destroyed, but as only buildings of Type 2 were burned, nothing additional can be learned there, and no further mention will be made of this place.

It would be well to state here that when the phrase "complete destruction" is used, it means that the part is destroyed so that it is unfit for further use. Under this, a disintegrated terra cotta floor, or a leaning brick wall, or a bent steel beam is destroyed, even if the part may be again reshaped and used.

No attempt will be made here to describe in detail the amount of destruction of any one building. Cases will be cited illustrating various points. It is believed that a description of the fire effects on different materials and upon their combination will be of more real interest. Reference will only be made to buildings of Types 3 and 4. Types 1 and 2 were completely destroyed, and Type 5 had no example of moment. In Type 2, the city ordinance allowed buildings 100 ft. high, if lathed with metal; and of 82 ft., if with wooden lath. No evidence is offered regarding this, as they were all destroyed.

Bearing in mind the definition of "complete destruction," it



FIG. 1.—EXTREME CASE OF EARTHQUAKE DAMAGE TO FRAME BUILDINGS IN SAN FRANCISCO. (IN CENTER.)



FIG. 2.—EARTHQUAKE DAMAGE TO MAIN BUILDING OF AGNEWS' ASYLUM, NEAR SAN JOSÉ.

can be said that all materials were destroyed when directly exposed to the fire for any length of time. Brick, terra cotta, granite, marble, sandstone, steel, cast iron, concrete, plaster, cement, timber —all failed. Especial emphasis is placed on this point. Anyone with an interest in any one material can find evidence to support a claim for it; yet, impartial observation leads to the conclusion that, when a material was subjected to what would be considered a test fire, it was destroyed.

Front Walls.—All ordinary methods of construction were exposed to the fire. Granite suffered more than any other stone, spalling badly wherever exposed. Marble fared nearly as badly, and sandstone slightly less. With all, there was complete destruction. No limestone fronts had been used. Of the terra cotta fronts, most were destroyed, for instance, the Bullock and Jones Building. Glazed terra cotta blocks, used in court walls, were generally cracked. Terra cotta brick spalled everywhere. The walls of the Mills and Merchants' Exchange Buildings are to be removed. Moulded terra cotta brick and pressed brick withstood the fire best of all, but were spalled where much exposed. Terra cotta brick with rounded corners fared best, sharp edges cracking off.

Either stone, brick or terra cotta was used around windows, and here the damage was the worst. In relation to this, it may be said that terra cotta is deceptive, in that it retains its form after being destroyed. Many fronts, apparently in good order, must be removed. In the Mills Building, there was hardly a window opening in which the terra cotta sills, jambs and heads were not badly cracked. From the street, they had the appearance of being in good order. Walls of ordinary red brick and mortar were destroyed in many cases, especially in buildings of Type 2, where the fall of the interior frame pulled down the wall. There are many instances of the integrity of such walls, especially at corners; while many of them were injured in the earthquake, it is not believed that this was a factor of much importance in the fire. The damage to standing walls in all buildings was the spalling of the red brick, sometimes to a depth of 1 in.

Foundations.—No foundations were found injured by the fire.

Floors.—Only two kinds of floors were exposed: terra cotta and concrete. Of the two, terra cotta suffered the more, being in all cases, where directly exposed, completely destroyed. Terra cotta floors, built with flat arches and with plaster applied directly, were all destroyed. The general effect was a spalling of the lower section of the tile structure and a disintegration of the mortar joints. The tile also became brittle, breaking with a slight blow. All terra cotta was of the dense type, no porous tile being used. In the James Flood Building, tile arches were used, being of the regular

arch construction. They were covered with 4 in. of concrete, and protected by a wire-lath ceiling. They escaped injury except where the ceiling lath fell, and there the lower layer spalled off.

Concrete floors generally had hung ceilings, and, where thus protected, were uninjured. Where exposed, the concrete is in most cases destroyed, for instance, in the Sloan, Rialto, and Aronson Buildings, and the Crocker Warehouse. The concrete is dry, and while in many cases hard, yet all the water has been burned out and it may be said to be destroyed, even if able to support weights. Floor coverings of wood invariably burned, adding to the destruction. Sleepers were generally burned. Surfaces of cement mortar fared much better, the linoleum covering remaining practically intact.

Partitions.—Partitions were of terra cotta tile, and of wire-lath and plaster, either solid or hollow. All kinds were destroyed. In the tile partitions the mortar joints were disintegrated, the plaster was destroyed, and the tiles were made brittle. One could pull down with the hand any partition in the Mills Building, all of which were of tile. Metal lath and plaster partitions were completely wrecked, but the lath might be considered as salvage. The use of wooden grounds around doors and transoms helped the destruction, but it is difficult to see what would have prevented the damage.

Steel Frame.—The steel frames were the least injured of any part of the various structures. Where properly protected, there was no injury. Where the protection was faulty, or where there was none, the destruction was complete.

Cast-iron columns were used in a few buildings of Type 3. As a rule, not as much care was taken to protect them as in the case of steel columns. Numbers of cases have been observed of the melting of cast-iron columns, especially lugs, in buildings of Type 2. In Type 3, the most conspicuous example is that of the Sloan Building, used as a carpet and furniture store. A number of columns in the basement, covered with one layer of lath and plaster, melted so that the metal ran together into a lump, lowering the floors from 1 to 4 ft., and completely wrecking the building. The basement was full of linoleum. In the Wells Fargo Building, with cast-iron columns protected by double lath and plaster, and used as offices, no damage resulted.

Steel columns fared about the same. In the Fairmount Hotel, probably 25% of the columns was destroyed. These columns had practically no protection, being built in between lath and plaster partitions. These partitions had interior blind spaces of from 6 to 18 in. in width, and, in many of the wall columns, the space extended from the first floor to the roof. To stiffen the partitions,

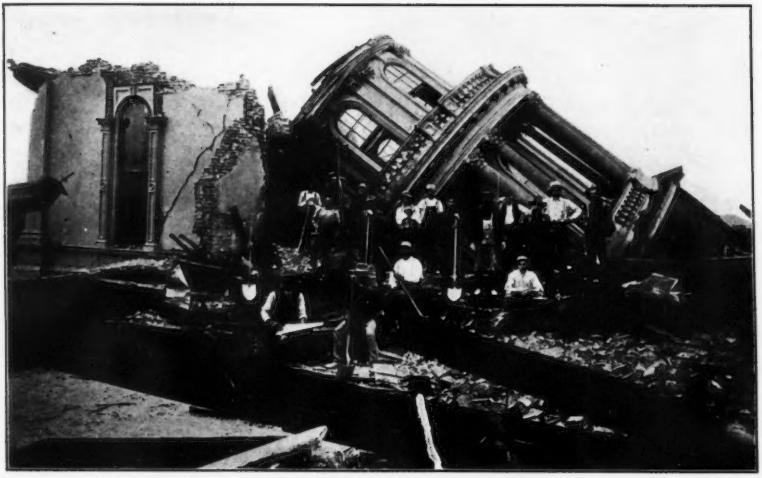


FIG. 1.—EARTHQUAKE DAMAGE, SECOND FLOOR OF COURT HOUSE, SANTA ROSA.



FIG. 2.—EARTHQUAKE DAMAGE IN OAKLAND. NOTE WALL CONSTRUCTION OF TOWER.

studding of timber, 2 by 4-in., 4 by 4-in., and 4 by 6-in., was used everywhere. The burning of the timber directly against the unprotected column, in additon to the general fire, destroyed it.

In the Hotel Alexander an apology of wire lath and plaster was used as a fire-proofing. It was cut into everywhere for door frames; and thirty-nine column sections were destroyed. In the Aronson Building, the terra cotta fire-proofing fell away, and ten column sections were buckled. One case of this kind occurred in the Mills Building, and several columns were bent, for the same reason. One column section was similarly wrecked in the Crocker Building, and two sections were bent in the St. Francis Hotel, where the tile fire-proofing had been cut away to allow the placing of rolling doors. It may be stated that every instance of failure can be thus explained.

Steel beams and girders were bent where unprotected, but remained uninjured otherwise. Much of the injury was suffered in first floors; basements and sidewalk beams, as a rule, having the lower flanges unprotected. Comment on protection is offered below.

Most roofs were simply of beam construction, similar to the floors, but the damage was generally less, owing to the protection afforded by hung ceilings. The trusses in the Mutual Life Building were covered with tile, which failed to protect, allowing the trusses to fall and damaging the supporting columns. A number of roofs were destroyed from lack of adequate protection, generally, where made of terra cotta, the Crocker and Spring Valley Water Company Buildings being examples.

Ceilings.—Where ceilings were made by plastering directly upon terra cotta, flat floor arches, they were completely destroyed. Where metal-lath, hung ceilings were used, the plaster was destroyed, but the lath generally remained in place, and was not damaged. Where copper wire was used to fasten the wire lath it failed, dropping the ceiling. Such wire should never be used.

Miscellaneous.—Vaults in offices, where made with doors set in a terra cotta, or wire-lath and plaster box, failed everywhere, the contents being burned. Vaults made with an iron box covered by fire-proofing fared much better. Safe deposit vaults in the basements of banks were uninjured, which suggests similar devices for the tenants of large buildings.

All plaster was destroyed. Marble tiling for floors was a complete failure. Marble treads for stairs failed, as also all wainscoting of that material, the marble being calcined.

Wire-glass covering of skylights resisted the fire well, except where the glass melted. Temperatures that melted glass were reached everywhere.

Metal-covered window frames, doors, and door frames were used

in the Kohl Building, the upper 6 stories of which were not burned. No opinion is offered, except that this building was not much exposed, the glass of the exterior windows not being even cracked. The metal trim undoubtedly acted to deter the spread of fire within the building.

Steel shutters were used in the Telephone Building, but it was completely burned. It is claimed that the fire entered through some unprotected windows.

Elevators grilles were generally destroyed, together with the cages and machinery above the basement.

Some question may arise as to the temperatures during the fire. Glass was melted everywhere. The softening of cast-iron columns in the Sloan Building has been referred to. There were numbers of cases of the actual melting of cast-iron columns, and in many buildings steel was melted. Cases of the latter were observed in a dry-goods store, where numbers of I-beams were fused; and also in a machine-shop, where steel rods were fused.

Conclusions.—Any deductions from the fire must be those based upon a general conflagration, and not those of an isolated fire. In view of the complete destruction of all materials it becomes a question as to what should be done to make a building fire-proof.

San Francisco was built probably in about the same way as other cities. It is an error to say that it was a wooden-frame city, as the business district was generally composed of buildings with brick walls. In among these had been constructed the so-called fire-proof structures, exposed on all sides to danger by the burning of the inflammable structures around them.

The only statement that can be offered is that the best insurance for buildings would be the isolation of a district containing nothing but fire-proof structures. A general conflagration would then be impossible. Manifestly, this is impossible in San Francisco, where business must be resumed with the least cost. In many cities, it would be good insurance for men owning large buildings to combine to buy out old and inflammable structures, either demolishing or rebuilding them. Otherwise, there remains the danger of general conflagrations, such as those at Baltimore and San Francisco, in which fire-proof buildings will be injured from 30 to 60 per cent.

Turning to the individual building, the question of the exterior walls must be settled. There does not seem to be much choice of material. Architectural considerations demand the use of brick, terra cotta, or stone. With a steel frame supporting the walls at each story, any local fire will destroy the nearby facing, but it may be removed without damage to adjoining parts. This cannot

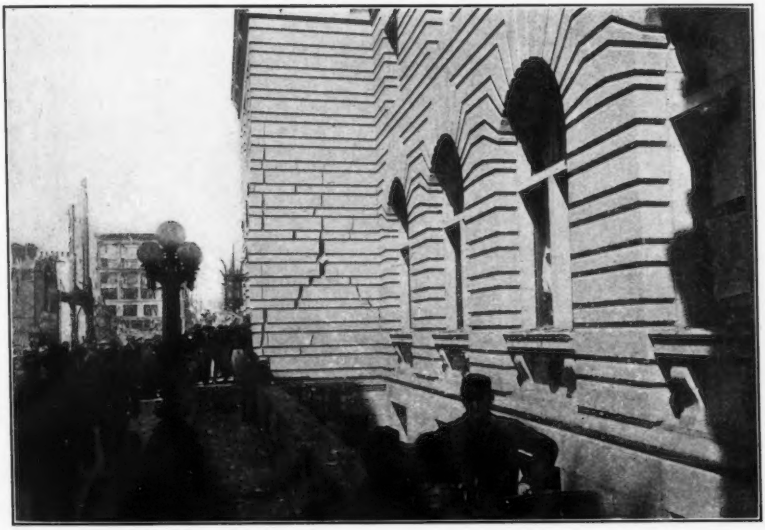


FIG. 1.—EARTHQUAKE DAMAGE, SAN FRANCISCO POST OFFICE.

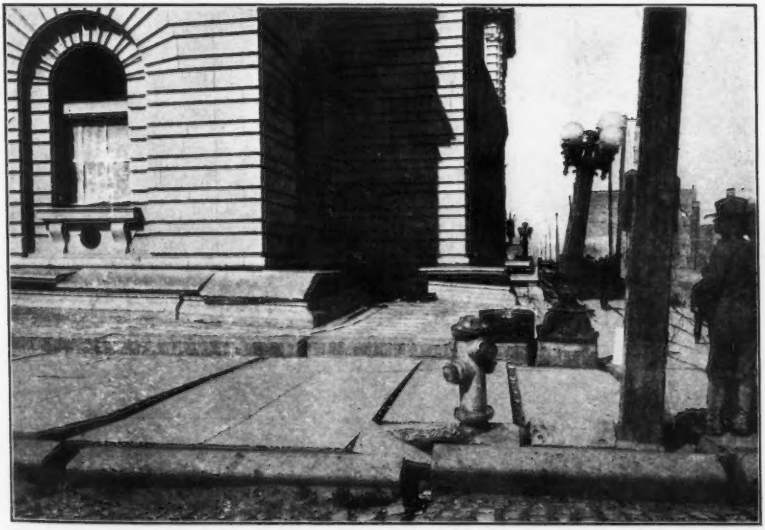


FIG. 2.—EARTHQUAKE DAMAGE, SAN FRANCISCO POST OFFICE, DUE TO SINKING OF GROUND.

be done when walls are self-supporting and the facing acts as a part of the wall. This risk of damage must always be carried, gradually becoming less as inflammable buildings are eliminated.

There is no doubt that the steel frame is adequate for all its purposes, but it must be protected. This brings up the general subject of fire-proofing, in which is involved the construction of floors and partitions, and ceiling and column protection. Where any reasonable protection was given the steel frames of buildings in San Francisco, the steel was uninjured, and hence the writers feel warranted in stating that it is possible to protect such a frame so that it will pass uninjured through a fire that consumes all parts that can burn.

It was stated previously that all materials were destroyed by fire; it follows, from this, that the destruction of fire-proofing must be expected, and that it will have to be restored after a fire. It becomes a question, then, of selecting the material that will stand up best, for the fire-proofing must retain its form, even if destroyed.

In the writers' judgment, the column should be of a closed form, such as channels and plates. This is preferable to latticed columns. For columns, the fire-proofing that will stand up best is red brick set in Portland cement mortar. Equal to this is a casing of solid concrete at least 4 in. thick, with a mesh of reinforcing metal. Examples were found in the St. Francis Hotel and Shreve Building, where the concrete was uninjured. In the Fuller Building, which was used as a paint and oil warehouse, the floors were of wood, and the columns were covered with from 4 to 5 in. of concrete. This protection held in place when the columns fell. It was completely destroyed, but the column shafts were protected. Next in order, and of equal merit as far as examples show, is the double wire-lath and plaster protection, which, in the Wells Fargo Building, afforded complete protection. In many buildings, columns were protected by one layer of lath and plaster, directly applied, and then the entire column, with pipes, etc., was enclosed by the regular partition. This afforded complete protection, and the Merchants' Exchange and Kohl Buildings are examples. The examples of the Fairmount and Alexander Hotels are not included, as obvious defects in design and execution warrant the statement that the columns in these buildings were practically unprotected. The same remark also applies to the melted cast-iron columns of the Sloan Building.

The remaining examples of column failures must be laid to the failure of terra cotta tile. The work in the Mills, Crocker, and Aronson Buildings was well done, but in all, and in the latter case especially, it failed utterly to afford complete protection. As the failure of one column section means the practical destruction of all

floors supported by that column, the results are serious. In justice to the terra cotta tile, it must be said that in the St. Francis Hotel, the Union Trust, and some other buildings, it stood up well enough to protect the columns. The writers believe, however, that it is the least valuable of all materials commonly used for fire-proofing.

For floor construction, some form of reinforced concrete is far preferable to tile. In all cases the record of concrete is better than that of tile. Connected with this is the protection of the lower flanges of beams and girders. The fire shows that a cover of lath and plaster directly upon the flange, protected again by the suspended ceiling, is the best. The layer of plaster alone on the flange will not protect. Neither will the thin piece of terra cotta strapped on. It may be stated here that one of the most obvious lessons taught by this fire is the protection to concrete floors and floor beams by the suspended ceiling of lath and plaster. In all cases where used, it afforded complete protection. Where not used, concrete was destroyed and beams were distorted.

The subject of partitions is bound up with that of column protection. Terra cotta tiles are inferior to lath and plaster, although both were destroyed. A partition may be destroyed, but, if it stands, it impedes the spread of fire, and, in this light, the lath and plaster type is superior to tile. It should be possible to construct better partitions, but as yet no better ones have been offered.

A logical deduction from the statement that all materials were destroyed is the conclusion that all structural parts of a building, of whatever material constructed, must be protected by another material which will be a more or less complete loss in a fire. This applies to a steel frame, to floors of any type, and to roofs. It is impossible to protect some parts, such as fronts, partitions, and other parts directly exposed. The floors and frame constitute the structural parts, failure of which means destruction of the building. All such should be fire-proofed. This remark applies with equal force to buildings with reinforced concrete columns, girders, beams and floors. As integral structural parts, they should be fire-proofed as well as similar members of a steel-frame structure, for concrete is destroyed by fire nearly as quickly as steel.

No further comment is offered, except the following. Buildings with wooden floors will be completely destroyed in a fire. Such parts as metal trim, wire-glass, and steel shutters, were not used to sufficient extent to warrant any definite conclusions, except to say that what showing there was was favorable. Whether this expense is warranted was not determined. Bad work and indifferent construction will cause any material to fail. Good work will enable a poor material to stand up. Fire-proofing should be continuous, and at no place should it be cut into for the passage of pipes, etc.



FIG. 1.—EARTHQUAKE DAMAGE, TOWER OF FERRY DEPOT. NOTE RUPTURED EYE OF DIAGONAL ROD.

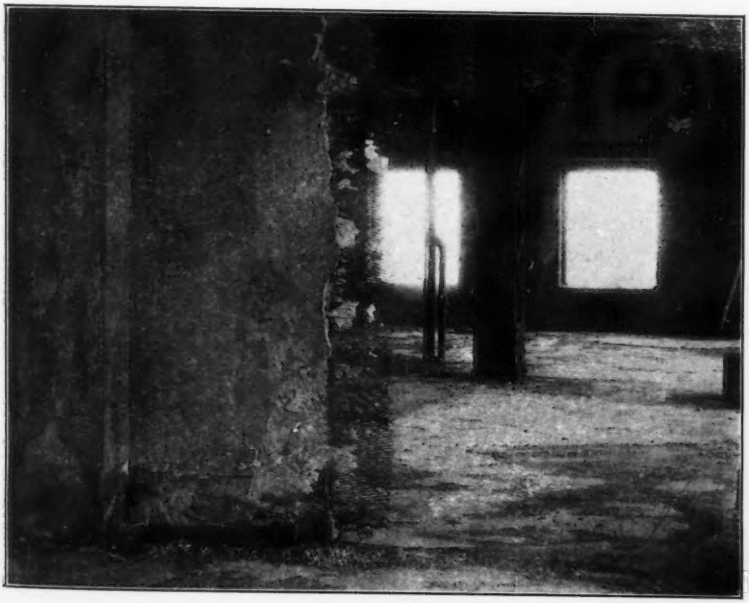


FIG. 2.—FIRE DAMAGE. LATH AND PLASTER PARTITION, TENTH FLOOR, ATLAS BUILDING.

The subject of pipes should be treated as it deserves, and proper ducts and shafts should be provided, instead of allowing them to be placed anywhere, where they will give the least trouble.

It is hoped that comment will be received on this report, but it is trusted that it will be in the nature of criticism, and not in the way of advocacy of some one form of construction.*

* This report was accompanied by 122 photographs, from which 34 have been selected for reproduction. They are shown in Plates XIX to XXXIII.

APPENDIX C.

REPORT OF COMMITTEE ON THE EFFECT OF THE EARTHQUAKE ON WATER-WORKS STRUCTURES.

COMMITTEE:
ARTHUR L. ADAMS, CHARLES D. MARX, CHARLES B. WING, C. E. MOORE, CHARLES GILMAN HYDE, C. E. GILMAN, GEORGE L. DILLMAN, FRANKLIN RIFFLE, PHILIP E. HARROUN.

The purpose of the investigation which has been made the basis of this report has been to ascertain the ability of the various classes of structures ordinarily used in the development and distribution of water supplies to withstand the violent shock of earthquake such as that which occurred in the coastal region of Central California on the morning of April 18th, 1906; and to draw such conclusions for improvement of design and for such increase of caution or confidence in the acceptance of established usages as the results seem to warrant.

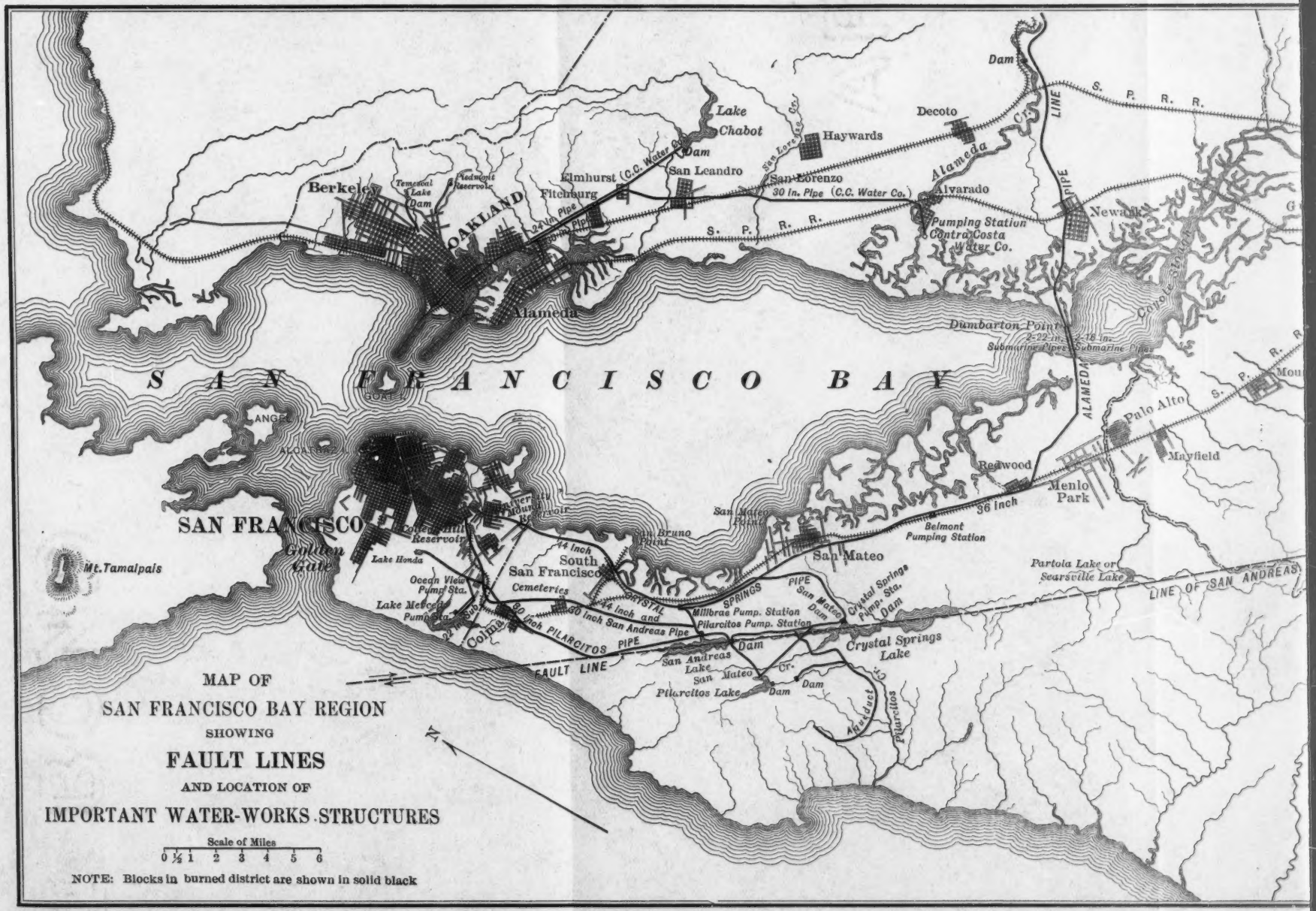
In this report, no attempt will be made to describe in detail, or even mention, all the many structures appertaining to the various systems of works in use for supplying water within the great area violently shaken. The prime purpose will best be subserved by taking up the various most important classes of structures, and by setting forth, in the case of each, such information as the Committee has been able to obtain, and any conclusions which it feels warranted in drawing therefrom.

The classes of structures considered are: Earth Dams, Concrete Dams, Distributing Reservoirs, Pumping Stations, Elevated Tanks and Stand-pipes, and Pipe Lines.

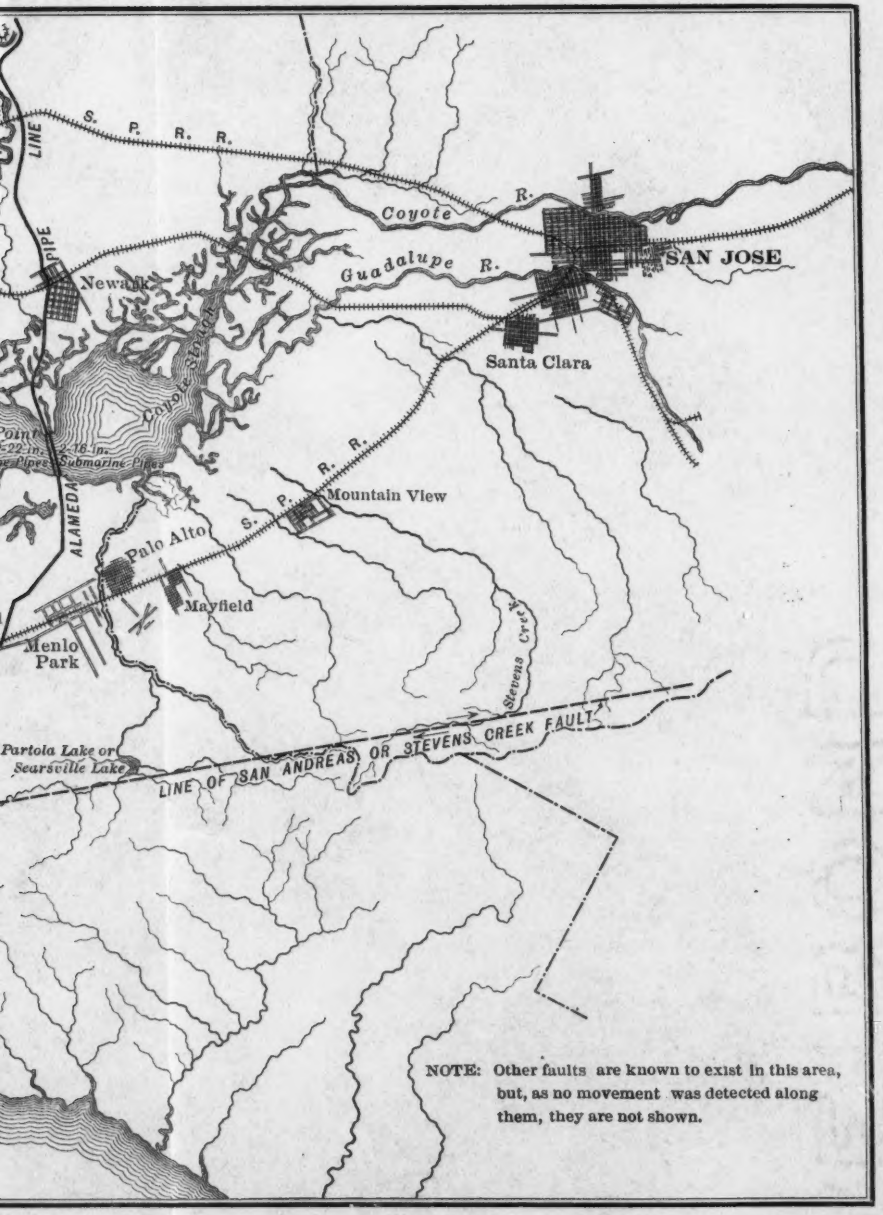
The locations of the important structures mentioned hereinafter, and their position with reference to the geologic faulting where the movement originated, are indicated on Plate XXXIV.

Earth Dams.—Centered about San Francisco there are several of the greatest earthen dams in the world. On the peninsula south of San Francisco, between San Francisco Bay and the Pacific Ocean, and immediately along the fault line or adjoining it, are three belonging to the Spring Valley Water Company and used as parts of the system supplying San Francisco with water. These are the Pilarcitos, the San Andreas, and the Upper Crystal Springs Dams.

As the permanent longitudinal displacement along the fault line in this region is from 6 to 7 ft., all these dams must have


S A N F R A N C I S C O B A Y
SAN FRANCISCO
OAKLAND
Alameda
Berkeley
Temescal Lake Dam
Piedmont Reservoir
Elmhurst (C.C. Water Co.)
Fitchburg
24 in. Pipe
Lake Chabot
Dam
San Leandro
San Lorenzo Cr.
Haywards
Decoto
San Lorenzo
30 In. Pipe (C.C. Water Co.)
Alvarado
Pumping Station Contra Costa Water Co.
Alameda Cr.
S. P. R. R.
PIPE LINE
Dam
Newark
Dumbarton Point
2-22 in. Submarine Pipes
16 in. Submarine Pipes
Coyote Slough
ALAMEDA
Palo Alto
Mayfield
Redwood
Menlo Park
36 Inch
Belmont Pumping Station
San Mateo Point
San Bruno Point
San Mateo
Partola Lake or Searsville Lake
LINE OF SAN ANDREAS
Mt. Tamalpais
Golden Gate
Lake Honda
Ocean View Pump Sta.
Lake Merced Pump Sta.
Cemeteries
South San Francisco
44 Inch
CRYSTAL SPRINGS PIPE
San Mateo Dam
Crystal Springs Pump. Sta.
Crystal Springs Dam
Millbrae Pump. Station
Pilarcitos Pump. Station
30 Inch San Andreas Pipe
24 Inch and 30 Inch PILARCITOS PIPE
Colma Cr.
FAULT LINE
San Andreas Lake
San Mateo Cr.
Dam
Crystal Springs Lake
Pilarcitos Lake
Dam
Aqueduct
Pilarcitos Cr.
MAP OF
SAN FRANCISCO BAY REGION
SHOWING
FAULT LINES
AND LOCATION OF
IMPORTANT WATER-WORKS STRUCTURES
Scale of Miles
0 ½ 1 2 3 4 5 6
NOTE: Blocks in burned district are shown in solid black


Dam
Lake
Chabot
Dam
San Leandro
Haywards
San Lorenzo Cr.
Decoto
Alameda Cr.
LINE
PIPE
Elmhurst (C.C. Water Co.)
Fitchburg
24 in. Pipe
San Lorenzo
30 in. Pipe (C.C. Water Co.)
Alvarado
Pumping Station
Contra Costa
Water Co.
S. P. R. R.
Alameda
Dumbarton Point
2-22 in. Submarine Pipes
16 in. Submarine
N C I S C O B A Y
ALAMEDA
Redwood
Menlo
Park
36 Inch
Belmont
Pumping Station
San Mateo Point
San Bruno Point
44 Inch
South
San Francisco
Cemeteries
San Mateo
Partola Lake or
Searsville Lake
CRYSTAL SPRINGS PIPE
44 Inch and 30 Inch San Andreas Pipe
Millbrae Pump. Station
Pilarcitos Pump. Station
San Mateo Dam
Crystal Springs Pump. Sta.
Dam
30 Inch PILARCITOS PIPE
Dam
Crystal Springs
Lake
FAULT LINE
San Andreas
Lake
San Mateo
Cr.
Dam
Pilarcitos Lake
Dam
Aqueduct
Pilarcitos


S. P. R. R.
LINE
PIPE
Coyote R.
Guadalupe R.
SAN JOSE
Newark
Santa Clara
Mountain View
S. P. R. R.
Palo Alto
Mayfield
Menlo Park
ALAMEDA
Stevens Creek
Portola Lake or Searsville Lake
LINE OF SAN ANDREAS OR STEVENS CREEK FAULT
NOTE: Other faults are known to exist in this area, but, as no movement was detected along them, they are not shown.

been shaken terrifically, especially the two which are directly on the fault line.

The Pilarcitos Dam is 640 ft. long on the top, and 95 ft. high; it has a top width of 24 ft. and slopes of 2 to 1 on both sides. It has a puddle core, 24 ft. thick, extending from 40 ft. below the bottom to the water level, and was built in 1864-66. It is 1¾ miles westward from the line of fracture. This dam was not injured.

The San Andreas Dam is 800 ft. long, 93 ft. high, and is of the same general type as the Pilarcitos Dam. It was built in 1868-70. The fault line passed across its east end, intersecting a natural ridge which was made a part of the dam at this point. The surface disturbance here was apparent over a width of about 150 ft. One of the cracks, without injury to the structure, intersected an inlet culvert built of concrete in which railroad iron was embedded. The brick-lined tunnel leading from the waste overflow was intersected by the fault line, and was fractured and offset in the general movement. The main body of the dam shows a crack, from 2 to 3 in. in width, extending longitudinally along the center line for the entire length of the dam. Some slight cracking in a direction transverse to the dam also occurred. No leakage through the dam resulted, and the earth structure may be regarded as wholly uninjured.

The Upper Crystal Springs Dam is about 75 ft. high, some 600 or 700 ft. long, and was built in 1878. It is of the same general type as the dams previously described. The original purpose of its construction is now changed, and at the time of the earthquake the water was at the same elevation on each side of it, so that it was not resisting any unbalanced pressure. This dam was crossed by the fault line at a point east of the center, and the two parts were offset about 6 or 7 ft. The fences on either side of the road passing along the top of the dam were straight prior to the disturbance. The top of the dam shows many longitudinal and transverse cracks. The former, while not continuous, appear along the entire length, being especially noticeable on the slopes. One is shown in Fig. 1, Plate XXXV. Some years ago this dam was raised quite a number of feet, in order to improve the grades of the county road which traverses it. This work is said to have been done with much less care than would have been exercised had the upper part been intended for use as a dam. This condition, and the high line of saturation resulting from its being submerged on both slopes, are accountable, no doubt in large part, for the formation of longitudinal cracks through a tendency of the slopes to take a flatter inclination when subjected to a violent shaking. To what extent the ability of the structure to resist the pressure of

water has been affected cannot be determined under the circumstances; but the nature and extent of its apparent injuries are not so severe as to indicate that there would have been serious danger of failure had it been acting as a true dam in service.

In addition to these structures, much interest attaches to the two smaller dams which, by closing each end of a saddle depression, form the Saratoga Reservoir of the San José Water Company, located in the Santa Cruz Mountains between Saratoga and Los Gatos. The fault line runs directly through this reservoir, and crosses both dams approximately at right angles. Near the east end of the North Dam transverse cracks are found extending through the body of the dam. Fig. 2, Plate XXXV, shows the crack on the wet slope of the North Dam. There was also a longitudinal crack through the dam, and some settlement of the inner slope. A transverse crack near the fault is shown in Fig. 1, Plate XXXVI. Though the reservoir was apparently full at the time, there is no evidence that any water escaped through the North Dam.

At the south end, the fault line crosses both the dam and a 10-in. cast-iron outlet pipe, which seems to have been shattered. A joint near the outer toe of the dam was also pulled apart. These pipe ruptures resulted in emptying the reservoir and washing out a considerable quantity of material from the South Dam, as shown in Fig. 2, Plate XXXVI.

On the eastern side of San Francisco Bay, in connection with the works of the Contra Costa Water Company, supplying the Cities of Oakland, Berkeley, and Alameda with water, are two very high earthen dams known as the San Leandro or Lake Chabot Dam and the Temescal Dam. In addition to these there is a third, of very recent construction, known as the Piedmont Dam.

The first of these dams was built in 1874-75, and is still the highest earthen dam in the world, the top being 127 ft. above the original surface on the center line. On April 18th the lake created by this dam was full to overflowing. The earthquake shock caused waves 3½ ft. high to break against the dam and pass over the spillways. Neither the dam nor any of its appurtenant structures were injured; nor were there left any evidences of its rough treatment.

The Temescal Dam is 105 ft. high, and was built in 1868. It was entirely uninjured.

The Piedmont Dam is a new structure, 260 ft. long on top, 45 ft. high at the inner toe, and 65 ft. high at the outer toe, with inner and outer slopes of 2 to 1. The inner slope was covered with 6 in. of concrete, with cement-plaster finish in lieu of the customary rip-rap, the concrete being placed in squares separated by asphaltum joints. The structure had been completed only a few months, and had just been filled for the first time. The rough



FIG. 1. - FISSURE IN SLOPE OF UPPER CRYSTAL SPRINGS DAM.



FIG. 2.—CRACKED AND DISPLACED RIP-RAP ON FAULT LINE AT DAM OF SAN JOSÉ WATER COMPANY NEAR SARATOGA.

Uber

shaking it received had the effect of settling it about 6 in. at the center and producing a few small transverse and longitudinal cracks near one end of the dam. No cracking of the concrete, and no material injury of any character resulted.

All these dams were constructed by the ordinary method of spreading in thin layers, wetting, and rolling. Against the outer slopes of the San Leandro and Temescal Dams had been deposited, by sluicing, a large additional quantity of material. These two dams have puddle heart-walls. The Piedmont Dam is built without a heart-wall of any kind, but the better grade of material had been placed adjacent to the upper slope.

Concrete Dams.—The only large masonry dams in the region seriously shaken are the great concrete dam near San Mateo known as the San Mateo or Crystal Springs Dam, and the Partola or Searsville Dam. The former is a part of the system supplying San Francisco, and the latter is a part of the system supplying Stanford University. That at San Mateo is one of the great dams of the world, its projected height being 170 ft., with a finished width at top of 25 ft., and a thickness at base of 176 ft. Its present height is 146 ft. Its length when completed will be 680 ft.

The Partola Dam is a much smaller concrete structure, at present 50 ft. in height, though projected to a considerable additional height.

Both are built of irregular, interlocked blocks, formed in place, but are substantially monolithic. Each stands about parallel to the fault line and within a few hundred feet of it. Neither structure gives any evidence of injury in any particular. It is impossible to say how they would have been affected had they stood at right angles with the fault line and had they been intersected by it, as in the case of the earthen dams previously described. It seems reasonable to suppose that, had they been sheared through vertically and offset, as in the case of the earthen dams, or had they been torn up as to their foundations, nothing worse would have occurred than the gradual loss of the water from the reservoir, as both structures are designed with heavy gravity sections.

Distributing Reservoirs.—Of the numerous distributing reservoirs in use in the disturbed region, most of which are lined with brick, concrete, concrete and asphalt, or with clay puddle protected with paving stones, the Committee has heard of only one being injured. This was the reservoir in San Francisco known as Lake Honda, a structure holding about 33 000 000 gal. This structure was formed by an excavation in the bottom of a ravine, the hills rising all about it, save at the outlet. The natural drainage is all diverted around it through a brick-lined tunnel. Either the reservoir has been dug to a depth well below the original natural sur-

face, even at the outlet, or there has been so great a volume of waste deposited below it, that it is practically wholly in excavation, without banks on any side. The lining, consisting of masonry of various classes, was broken to an extent calling for repairs.

The slope, on the west side consisting of very sandy soil, was supported by a retaining wall which constituted the side of the reservoir basin. This wall consisted of a number of brick buttresses between which were horizontal arches, also of brick. The effect of the shock was to rupture this retaining wall, which failed by shearing near the bottom of the reservoir, although irregular cracks in one place extended to the top of the wall.

Pumping Stations.—On the peninsula between San Francisco Bay and the Pacific Ocean there are, in connection with the San Francisco Water-Works, six important pumping stations. Two of these are within the built-up sections of San Francisco, one is at Lake Merced, one at Milbrae, one at Belmont, and one near the San Mateo Dam. These stations are all equipped with water-tube boilers and horizontal, cross-compound, crank and fly-wheel, pumping engines of capacities (save for the last-mentioned plant) varying in different engines from 5 000 000 to 8 000 000 gal. in 24 hours. Each station contains a number of pumps; the Belmont Station, being the largest in total capacity, contains five pumping engines.

Save for the two stations in the built-up sections of San Francisco, individual, guyed, steel stacks were used; and the buildings were of corrugated-iron construction, supported on timber frames. Of the two plants in San Francisco, one was housed in a substantial brick building, and the other in an old structure partly brick and partly corrugated iron; and both were supplied with brick stacks.

These pumping plants did not suffer any material damage affecting their serviceability, probably because their foundations were sufficiently massive to cause important units to move as a whole.

On the eastern side of San Francisco Bay there is an important pumping station from which about one-third of the water supply for the cities on that side is supplied. It is on the marsh land near the Bay shore, one mile west of Alvarado. It consists of two horizontal, cross-compound, crank and fly-wheel engines, each having a capacity of 5 000 000 gal. per day, and a full equipment of boilers, all housed in a brick structure. Individual, guyed, steel stacks are used. The engines, boilers, and building are supported on pile and concrete foundations of excellent construction. Although the brick walls of a part of the building were damaged so badly as to require reconstruction, the machinery equipment was not damaged in any particular.

The fuel-oil tank, having a capacity of 30 000 gal., holding at

FIG. 1.—TRANSVERSE CRACK IN DAM OF SAN JOSÉ WATER COMPANY NEAR SARATOGA. THIS CRACK IS ALONG THE MAIN FAULT LINE.

FIG. 2.—HOLE IN DAM OF SAN JOSÉ WATER COMPANY, NEAR SARATOGA. THIS HOLE IS NEAR THE MAIN FAULT LINE.

the time about 20 000 gal., supported by a timber grillage resting on the surface of the ground at an elevation of about 3 ft. above the bed of a creek near by, was so violently shaken that several thousand gallons of oil were thrown out, the roof was thrown off, and the foundation settled about 2 ft., breaking all the pipe connections. During the quake the channel of the creek disappeared, its bottom being raised to the general level of the adjoining land.

Elevated Water-Tanks and Stand-Pipes.—At Milbrae and Belmont, on the western side of San Francisco Bay, there are two stand-pipes of considerable height and small section, stiffened for their entire height by an enclosing braced timber tower. These pipes are used, in lieu of relief valves, to control the pressures at the pumping stations of the Spring Valley Water Company at these places.

At Agnews and Santa Clara, south of the Bay, there were elevated tanks, almost, if not quite, identical in design. They consisted of four 45 000-gal. wooden tanks supported on a steel frame 80 ft. in height.

There were also in the disturbed area many other structures of less magnitude, consisting of wooden tanks supported on timber towers.

Of the structures connected with public water-supply works, of sufficient importance to warrant special mention, only one was wrecked, although many low tanks used for road sprinkling, and others for locomotive water supply on the railroads, were thrown down. This wrecked tank was the one at Santa Clara, previously mentioned. Plates XXXVII and XXXVIII show its appearance during construction and before and after the failure. Concerning this structure, the designing engineer, C. E. Moore, M. Am. Soc. C. E., residing at Santa Clara, says:

"At Santa Clara the shake was especially violent at the pumping station; and near here the 12-in. supply pipe was broken, evidently by the upheaval. The pipe was shattered at the top and the broken bottom so telescoped as to produce an overlap of 1½ in. There is very decided evidence of wave action and consequent vertical motion. The 10-in. stand-pipe leading to the tanks was lifted out of its connection with the main, stripping the threads connecting it to a cast-iron flange.

"The water-tower itself was wrecked, but in such a manner as to testify strongly to the ability of a steel frame to withstand tremendous wrenches.

"The tower was of steel, 80 ft. high, and was made up of sixteen Z-bar columns, four rows of four each, carrying four rows of plate girders. Resting on the plate girders were 15-in. I-beams forming the floor system. The load consisted of four tanks with a total capacity of 180 000 gal. At the time of the disaster, there

were in the tanks about 125 000 gal. As gathered from those who observed this structure at the time, and from the position of the parts, the action was about as follows:

"The structure swayed violently. At the same time the tanks lifted from their setting and moved toward the south in a series of lurches. Finally, the two south tanks shot off from the floor and struck the ground, about 75 ft. from the tower. The two north tanks had moved to the extreme southern portion of the floor. The earthquake was then practically over. The structure ceased to sway, and stood upright. The movement of the tanks, however, had turned over some of the floor beams, and, being unable to carry the load in this position, they were bent downward. Their ends slipped from their support, letting fall the two remaining tanks, which in falling wrecked the tower.

"The tanks carried with them the lateral bracing, and pulled down the columns. On the north side many of the columns still stand intact with all lateral and sway-bracing uninjured, excepting the top story, which was pulled down by the girders.

"The fall took place several seconds after the shake was over; and the tanks seemed to the observers to settle slowly through the floors.

"The structure will probably be rebuilt along the original lines, as much of the material is uninjured. Additional bracing, however, will be placed between the girders to resist overturning; and, in place of the four wooden tanks, will be substituted one large steel tank anchored to the I-beams.

"* * * Had these features been embodied in the original design, I am of the opinion that the structure would now be standing. The possibility of such movement in the tanks, however, was never contemplated in the preparation of the plans."

The lesson to be drawn from this failure is evidently the necessity for thorough floor bracing and the secure anchoring of the load, as Mr. Moore has pointed out. With such precautions, it seems evident that such structures can more successfully resist earthquake shock than can most buildings.

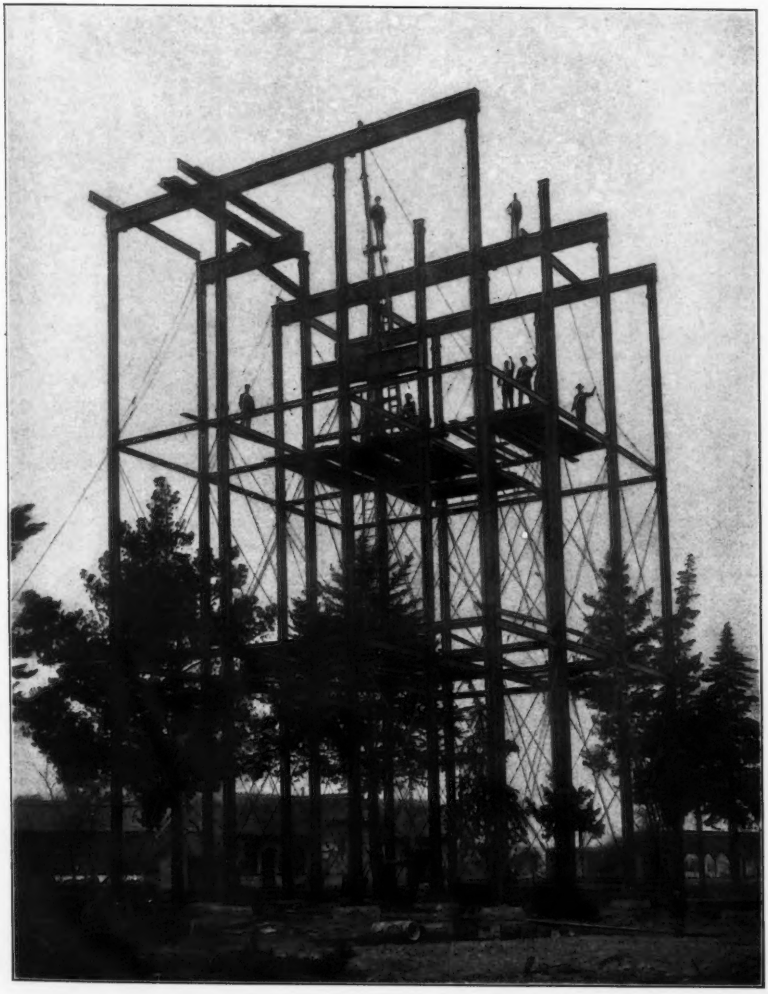
Pipe Lines.—The effect of the earthquake upon pipe lines and conduits generally depends:

First, upon the character of the foundation in which the structure is placed, as to whether it is firm and unyielding or such as will settle or displace seriously under violent agitation, such for instance as marsh, filled, or any soft alluvial soil;

Second, upon the character of the structures supporting the conduit if laid above ground; and

Third, on whether the structure is intersected by the fault line.

As far as the Committee has been able to ascertain, no considerable damage resulted to any pipe line which had been laid in firm ground.



WATER TOWER, SANTA CLARA WATER-WORKS, IN PROCESS OF ERECTION.

All important failures occurred either where they were supported above the ground on wooden trestles; where the shock produced serious and unequal settlement; where subject to the suspicion of having been strained from other causes; or where intersected by the fault line.

Of the three, long, riveted-iron, pipe lines leading from storage reservoirs into San Francisco, the middle one, 36 in. in diameter, leading from San Andreas Reservoir, was fractured at one point only. This was at Baden, where the pipe crossed a piece of marsh land on a wooden trestle. A slip joint had been provided at this point, and the amount of movement was restricted by four bolts attached to lugs riveted to the pipe on each side of the joint. The ¼-in. sheet to which these lugs were attached was torn out. Fig. 1, Plate XXXIX, shows the location of the break and the appearance of the pipe after temporary repairs had been made.

The 44-in. pipe leading from the San Mateo or Crystal Springs Reservoir into San Francisco had three breaks known to the Committee. Two of these were not serious. The third was the most extensive which occurred at any point about the Bay, save those immediately on the fault line hereinafter mentioned. This was at the crossing of the San Bruno Marsh, where, for a distance of about 2 000 ft., the pipe was supported upon trestle bents resting on a pile foundation. The pipe was pulled apart at a number of places, and nearly all of it was thrown entirely off the supports on either side. The photograph, Fig. 2, Plate XXXIX, taken after making repairs to the pipe, shows the location, and the character of the work during reconstruction.

The trestle supporting the pipe was no doubt still substantial enough to meet all conditions other than the unusual one by reason of which it was destroyed; but many of the timbers were badly decayed, and it is possible that this contributed to its destruction. This possibility is supported by the fact that no breaks have been observed at other points where this same line, supported on trestles, crosses marsh land. In these instances, the trestles were in good condition, but were not nearly as long as at the San Bruno crossing.

The 12-in. cast-iron pipe, 5 miles long, leading from the Searsville Reservoir to Stanford University, was cracked in three places. All occurred on horizontal curves. One was a fractured bell, and the other two presented longitudinal cracks, 4 or 5 ft. long. None was accompanied with evidence of earth displacement.

The pipe line leading from the Pilarcitos Reservoir to Lake Honda in San Francisco is, in small part, of 24-in. cast iron and 22-in. riveted iron, almost all of it being 30-in. riveted iron. It is located for some miles along the route of the ancient geologic fault on which the movement of April 18th occurred, and is

crossed and recrossed by it many times. The permanent longitudinal movement was in general from 6 to 7 ft., and wherever crossed by the fault line, the pipe, whether of cast or riveted iron, whether buried in the earth or carried on a trestle, was badly shattered, the direction of crossing determining whether the pipe was torn apart or telescoped. Figs. 1 and 2, Plate XL, illustrate typical fractures. At one point a trestle, crossing at a point where the pipe departs some distance from the fault line, was completely destroyed, the entire trestle and pipe line being thrown clear off its original site. Figs. 1 and 2, Plate XLI, show quite clearly the appearance of the surface fracture of the ground along the line of movement in the immediate vicinity of the pipe line, it being discernible in the latter picture as far as the horizon. Fig. 1, Plate XLIII, shows by the offset in the fence the 6½ ft. of longitudinal displacement.

It is evident enough that no precaution can prevent the failure of a structure where crossed by a fault line in the event of a movement as great as that which here occurred.

In San Francisco, all serious fractures of water mains, as a result of the earthquake, were due to lateral displacements, or subsidences of filled or soft ground across which, unfortunately, the main supply pipes from the lower and middle service distributing reservoirs passed. The map, Plate XLII, shows these areas bordered with a heavy line where clearly defined and with a broken line where not so distinctly and connectedly traceable. The displacement laterally amounted in places to as much as 6 or 7 ft.; vertically, it amounted to several feet. Fig. 2, Plate XLIII, gives some idea of the extent of this movement, both laterally and vertically, at Valencia and 18th Streets, where one of the most serious breaks occurred. It also shows the pipes laid temporarily on the surface to replace those parted underground.

It is evident that no precautions, save the entire avoidance of such localities in selecting the routes of main lines, can safeguard a pipe system against almost instant disability in event of causes leading to displacements of such magnitude. If entire avoidance is not possible, in some cases partial or entire immunity from risk might be found in supporting the pipes on deep pile foundations extending well below the compressible soil, and in the use of heavy flexible joints across lines of probable separation.

Extending from Bakersfield, in the south central part of the State, to Point Richmond, on the east side of San Francisco Bay, the Standard Oil Company has an extra heavy 8-in. steel screw pipe for conducting oil, by relay pumping, a distance of 300 miles. Mr. Page, the engineer in charge, reports the line absolutely uninjured.

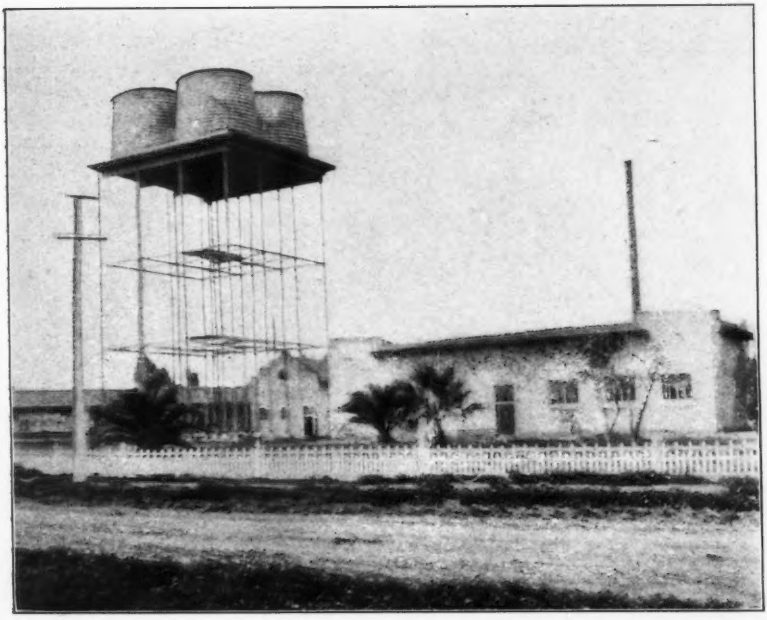


FIG 1.—WATER TOWER, SANTA CLARA WATER-WORKS, BEFORE ITS DESTRUCTION.

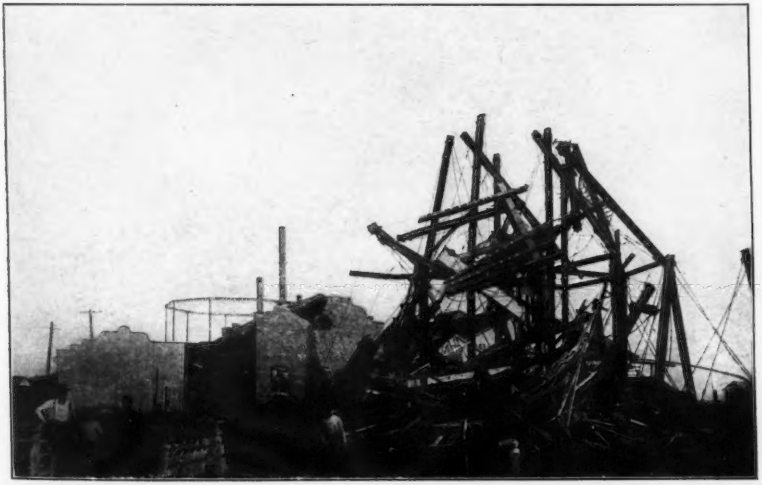


FIG. 2.—WATER TOWER, SANTA CLARA WATER-WORKS, AFTER ITS DESTRUCTION, APRIL 18TH, 1906.

On the pipe lines of the Contra Costa Water Company, supplying the cities on the eastern side of San Francisco Bay, a few ruptures occurred, all of which were in marshy or low-lying alluvial soil. Because of a fortunate duplication of important pipes, and an ample storage at Lake Chabot, none was so serious as to interfere with the continuity of the service, to any section of the region supplied, for more than 2 or 3 hours.

At Alvarado, near the pumping station, the 30-in. riveted-iron force main conducting the water to Oakland crosses the Alameda Creek on a short bridge. At a point just above the ground, at one end of the bridge, the pipe was pulled apart by the shock, and the two ends jammed against one another three times by the succeeding vibrations, the abutting edges of the sheets cutting into each other at different places each time a total distance of 5 in. The photographs of the two courses taken after their removal, Figs. 1 and 2, Plate XLIV, show the cut edges on opposite sides of the pipe. A short distance from this point, a renewal of the 30-in. pipe had in recent years been made with 24-in. pipe supported for one mile on two-pile bents spaced 29 ft. between centers. In this pipe was placed a 24-in. stop-gate resting on a concrete foundation. The piles under the pipe were not deeply placed; and the shake operated to settle them irregularly, some going down as much as 6 in. This did not damage the pipe, but brought a strain on the gate which broke off the flange.

A 24-in. riveted pipe lying in a street leading across a tide marsh in Oakland was pulled apart 5 in. and displaced 8 in. laterally by the settling of the entire street.

One 12-in. cast-iron pipe near the water front in East Oakland was drawn apart at the joint, and one or two breakages occurred on a long line of 8-in. pipe leading to the Southern Pacific Railroad Broad-Gauge Pier.

These were all the breaks that occurred on the several hundred miles of pipe in use on the east side of San Francisco Bay.

Conclusions to be Drawn.

The conclusions of the Committee are as follows:

First.—That greater attention in the future should be given to the avoidance, when possible, of threatening geologic faults, in the location of important water-works structures, than has sometimes been given in the past.

Second.—That skillfully designed and well-built earthen dams are structures proven by the great earthquake of April 18th, 1906, to be of great stability, and deserving of increased confidence.

Third.—That concrete dams of gravity section are able to withstand earthquake shocks of great severity without damage.

Fourth.—That distributing reservoirs, pumping machinery, elevated tanks and stand-pipes, if made secure as to foundations, and intelligently designed along lines of the best accepted practice, will be found capable of withstanding earthquake shocks sufficiently severe to work the general destruction of most buildings.

Fifth.—That pipe lines or conduits, of any character whatever, are almost certain to fail when intersected by a plane of large movement, whether that movement be in the nature of a faulting, or a sliding or settling of the earth in consequence of earthquake shock; and that in choosing locations for such structures it is prudent, as far as practicable, to avoid localities subject to such movements.

That in planning distributing systems for cities, the important supply pipes should be located along routes carefully selected for stability; and that areas liable to serious disturbance should be so segregated in the piping system as to make them easily and quickly separable from the remainder of the system.

Sixth.—That close adherence should be given to the recognized standards of the best present practice, such as the use in distributing systems of an abundance of suitably placed gates for isolating different pipes and different sections; the preservation of such gates in working condition; and having their location easily ascertainable, both in the street and in the office records; the duplication, along widely separated routes, of the critically important main supply pipes; the maintenance in as close proximity as may be to the centers of use of an ample storage supply of water; and the use of types of substantial design in working out plans for structures subject to possible earthquake shock.

In conclusion, the Committee gratefully acknowledges its obligation to those who have rendered to it valuable aid, and particularly to the officials of the corporations controlling the water-works, for facilities for making inspections.*

*This report was accompanied by 29 photographs, from which 17 have been selected for reproduction. They are shown in Plates XXXI to XLIV.]

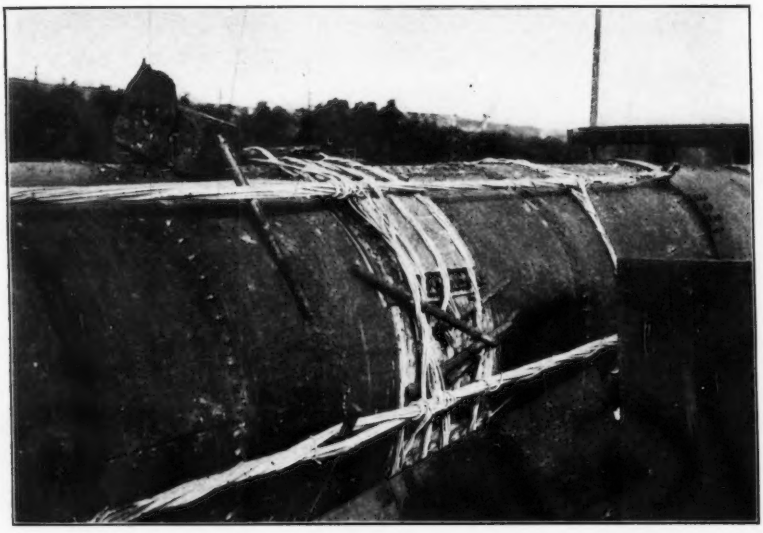


FIG. 1.—SAN ANDREAS 36-IN. PIPE LINE NEAR BADEN, AS TEMPORARILY REPAIRED.

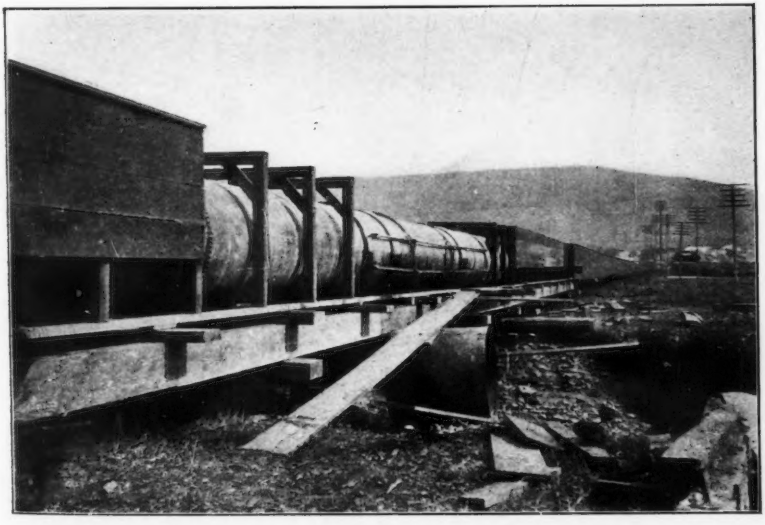


FIG. 2.—CRYSTAL SPRINGS 44-IN. PIPE LINE CROSSING SAN BRUNO MARSH.

Brill

APPENDIX D.

REPORT OF COMMITTEE ON THE EFFECT OF THE EARTHQUAKE ON LOCAL TRANSPORTATION AND LIGHTING PLANTS.

COMMITTEE:
A. M. HUNT.

Street-Car Tracks.—The injury caused to the street-car tracks was relatively slight. Where the tracks crossed the areas within which there was actual displacement of the ground, they were moved bodily, and there was serious sinking. Wherever this occurred, it was on ground that had been filled.

The slots of cable roads were carefully inspected after the fire, and in numerous places in the burned district were found closed. A characteristic closure of the cable slots is shown by Plate XLV. Except within the areas of slips, above noted, these points, with few exceptions, were found only in the burned district, and the evidence points to its being due mainly to expansion caused by the excessive heat. The fact that the Geary Street line, which is a cable road, operated for several hours after the earthquake, is very pertinent.

In the opinion of the Committee, and judging from the available evidence, any of the cable lines, except the Valencia Street line, could have been put in condition to operate, as far as the cable slot and conduit are concerned, in a few days, had not the fire followed the shake. The result of the fire and the falling debris was to put them entirely out of business, and make the amount of work necessary to put them into shape very serious.

Many of the trolley lines outside of the burned district were in such shape that they could have been operated at any time, but, owing to the fire hazard from the tangle of other wires, and the lack of water in many districts, they were not started for some days.

The trolley lines unquestionably substantiate the claim that such systems are flexible, and admit of emergency work to an extent not equalled by any others.

The Bryant Street power-house of the United Railroads was practically uninjured. The North Beach plant of the same company was temporarily crippled by the brick stack being shaken off and the roof collapsing.

Gas Plants.—Immediately after the earthquake, all gas was shut off the city lines, but sufficient gas was in the mains to cause

numerous explosions as the fire progressed. With the exception of the North Beach plant, the various gas-works were uninjured. The damage to mains was principally due to explosions.

As service was gradually restored, it was found that the house pipes, except in very few instances, were not damaged.

Electric Light Plant.—The electric lighting plant of the San Francisco Gas and Electric Company suffered very little injury by the earthquake, but the fire destroyed all the distributing substations, and played havoc with the overhead distributing lines. The underground conduit system and the Edison tubing came through both earthquake and fire in very good shape.

Miscellaneous.—Brick stacks of power plants were in most instances broken off, while well-guyed, steel stacks stood without injury.



FIG. 1.—BREAK IN PILARCITOS PIPE LINE.



FIG. 2. BREAK IN PILARCITOS PIPE LINE.

APPENDIX E.

REPORT OF COMMITTEE ON THE EFFECT OF THE EARTHQUAKE ON RAILWAY STRUCTURES.

COMMITTEE:
J. H. WALLACE, H. C. PHILLIPS, R. M. DRAKE, E. M. BOGGS.

Within the area of destructive effect of the earthquake of April 18th, 1906, the following railroad companies are operating: Southern Pacific, Atchison, Topeka and Santa Fé, California Northwestern, and North Shore.

In common with other property owners, they all suffered more or less from the falling of chimneys and cornices, the cracking of brick walls and the falling of old and weak buildings.

The structures peculiar to railroads, which were affected, are embankments, trestles, bridges, tunnels, and water- and oil-tanks.

Embankments.—Embankments across marshes, or with soft strata underlying them, settled more or less. In some cases the settlement was vertical; in other cases there was considerable horizontal with the vertical movement.

At one point on the marsh between Benicia and Suisun, on the Southern Pacific, the settlement was 11 ft.; at another point, 5 ft. These were nearly vertical.

Between Niles and San José, on the Southern Pacifc, there was at one point a displacement of 3 ft. horizontal, but the vertical displacement was only 6 in.

On the North Shore, about 2 miles north of Point Reyes, the road, originally, had been constructed with pile trestles across several arms of Tomales Bay; these trestles had been filled about 15 years ago, the road-bed being about 8 ft. above ordinary high tide. Two of these embankments, 2 200 ft. and 900 ft. long, respectively, sank until the water at high tide washed over the rails.

Settlements of this character, and of more or less severity, were common on all railroads operating about the Bay of San Francisco and its tributaries.

Trestles.—Trestles over marshes suffered more or less from the movement of the soft material into which the piles were driven. The most serious damage was at Fallons, on the North Shore, where a trestle, 600 ft. long and 70 ft. high, was thrown down. This trestle was constructed of framed bents on piles. Portions of the trestle over Lagunitas Creek, about a mile from Point Reyes, were thrown entirely off the piles, the piles themselves being moved down stream.

On the other roads the effect on trestles was very slight.

Draw-Bridges.—Draw-bridges across the little creeks and inlets around San Francisco Bay, being generally on soft ground, were affected by a slight movement of their piers, in many cases resulting in the bridge binding so that it could not be opened until some repairs were made.

The draw-bridge at Black Point, over Petaluma Creek, on the Sonoma Branch of the California Northwestern, was open at the time of the earthquake, and was thrown off its center 2 ft. to the east and 1 ft. to the north. This is a steel structure, 220 ft. long, on four iron caissons, filled with concrete, on pile foundations.

Fixed Bridges.—With a few exceptions, fixed bridges were not affected seriously. The bridges over the Russian River, at Healdsburg, and at Bohemia, on the California Northwestern, were both shifted slightly on the piers at one end.

At Duncan Mills, on the North Shore, a combination span, 120 ft. long, had the eye-bars in the lower chord buckled by movement of the abutments toward each other.

The Southern Pacific Bridge across the Pajaro River, at Watsonville, consisting of four 80-ft. wooden spans on pile piers, had the second pier from the east end moved (up stream) about 3 ft.

The bridge across the Pajaro River, near Chittenden, on the Southern Pacific, was badly damaged. The "line of fault" crosses this bridge near the west end. The bridge consists of three 120-ft. riveted spans with 50-ft. girders at each end. The general effect of the movement of the earth along the fault line was to increase the distance between the east and west abutments by 3.5 ft. The shock affected all piers and abutments more or less. Fig. 3 is a plan showing the original position of this bridge and the displacement of the piers; and Figs. 1, 2, and 3, Plate XLVI, are photographs of some of the piers.

At the east abutment, or Pier 1, the wing-walls cracked and settled about 1½ in. At Pier 2, the coping stone was displaced. Pier 3 was moved eastward from its original position 0.55 ft.; the north end settled 4 in., and the south end was raised 2 in. The coping stone was loosened. This pier cracked in two places, the cracks being horizontal; they probably occurred along the line marking the end of a day's work.

Pier 4 was moved westward 0.8 ft. at its center, and was twisted slightly, the movement being a little more at the south than at the north end. It was raised about 0.16 ft. at the south end and about 0.02 ft. at the north end. This pier has a horizontal crack, probably on the line marking the end of a day's work. The portion above the crack moved, with reference to the portion below it, eastward 0.16 ft. The lower portion of the pier actually moved westward 0.8 ft.,



FIG. 1.—SURFACE INDICATIONS OF FAULT LINE ALONG THE PILARCITOS PIPE LINE.



FIG. 2.—SURFACE INDICATIONS OF FAULT LINE ALONG THE PILARCITOS PIPE LINE.

SKETCH SHOWING DISPLACEMENT OF PIERS OF THE PAJARO RIVER BRIDGE
AFTER THE EARTHQUAKE OF APRIL 18TH 1906,

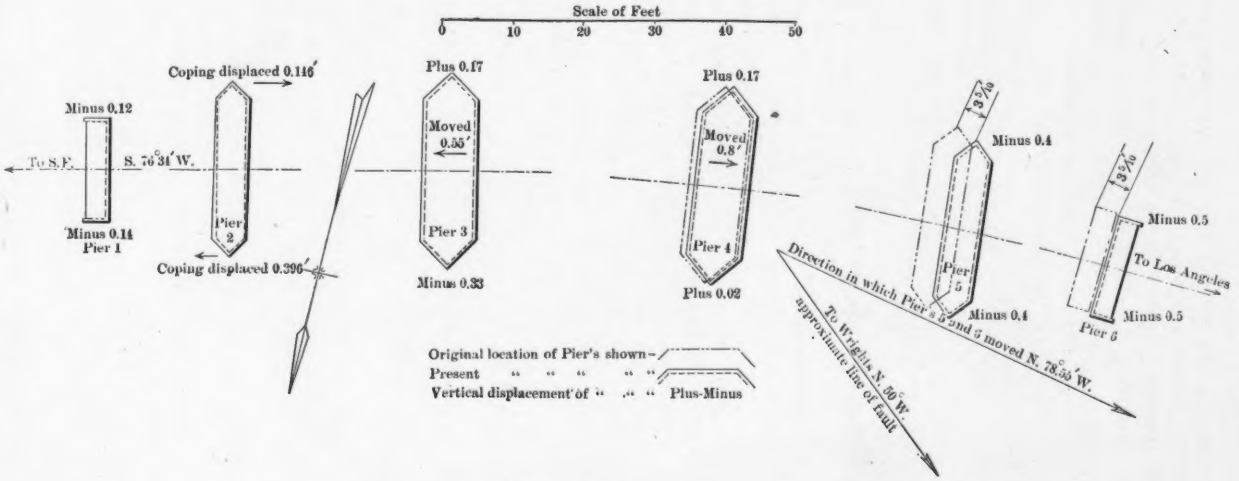


FIG. 3.

as noted above. The coping stone was loosened but not displaced to any extent.

The base of Pier 5 was moved westward 3.5 ft., and settled 0.4 ft. The pier broke along a horizontal line close to the ground surface, and the upper portion was moved eastward, with reference to the lower portion, 0.25 ft. The coping was torn from the top of the pier, being dragged by the end of the span anchored to it about 2 ft. from its proper position.

Pier 6, or the west abutment, was moved 3.5 ft. eastward, but does not appear to be damaged.

The end of the 50-ft. girder which landed on this abutment was dragged off the bridge seat, but did not fall, being held up by the fastenings of the rail and the riveted connections to the next span to the east.

Piers 1, 2 and 3 are founded on shale; Pier 4 is founded on sandstone at the south end and on shale at the north end, the greater part of the pier being on shale. Piers 5 and 6 are on sandstone.

From this bridge to the line of fault in Wright's Tunnel, the course is N. 50° W., which corresponds with the direction of the line of fault in the tunnel at Wright's.

The bridge was built in 1900, replacing a wooden bridge. In 1890 there was an earthquake which threw the bridge out of line, one end being shifted, with reference to the other, about 1 ft.

Tunnels.—In general, tunnels seem to have been affected only by the displacement or loosening of the material in the sides and roof, caused by the shaking of the ground. The effect of this was to crush the timbers.

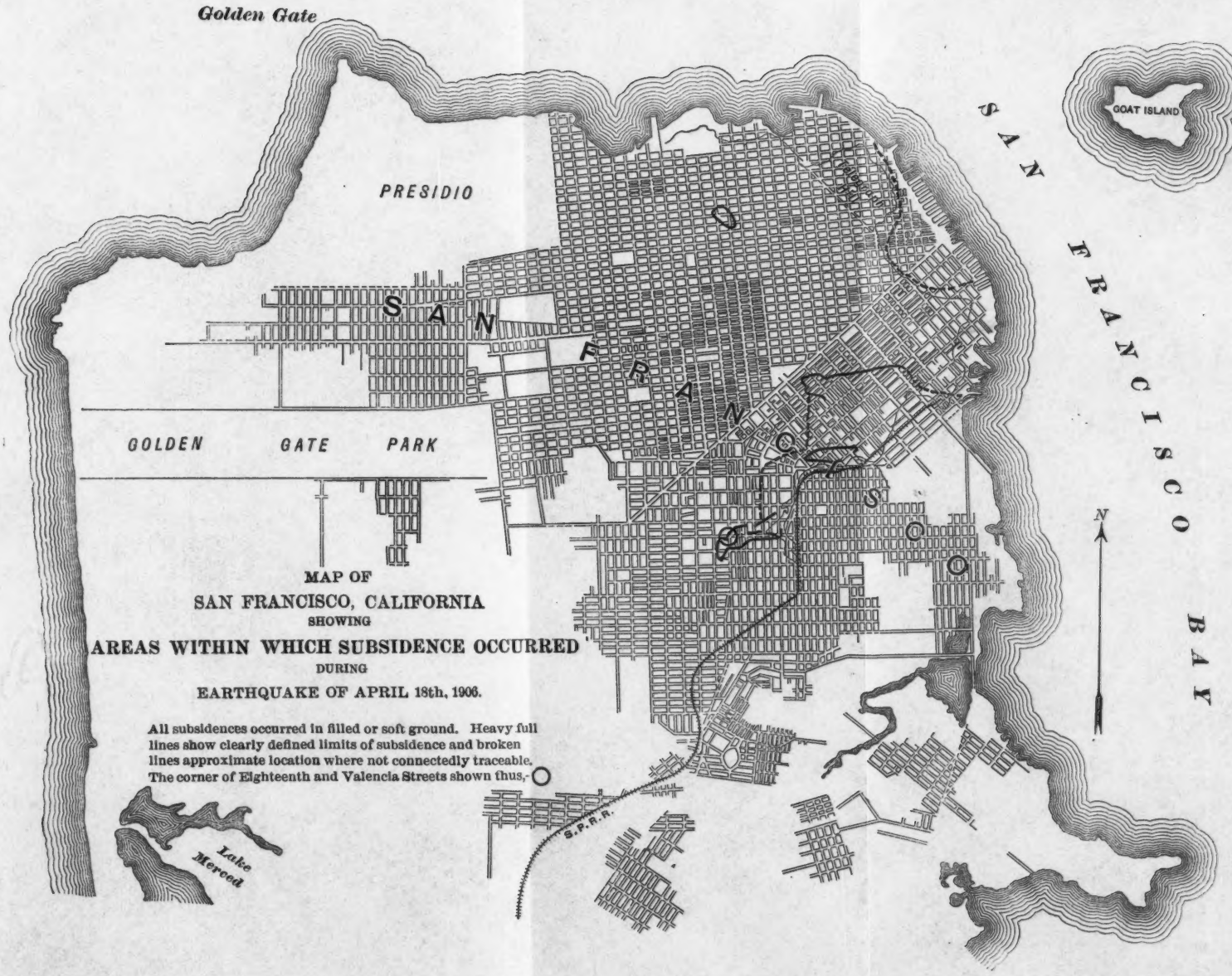
The new tunnels being constructed by the Southern Pacific Railroad on the Bay Shore line, in the southern part of San Francisco, were not injured at all.

The tunnel at Wright's Station, on the South Pacific Coast Railway (Southern Pacific Company), was on the line of the fault, and suffered considerable damage. The tunnel is 6 225 ft. long. The line of fault crosses the tunnel about 400 ft. from the north portal; the movement at this point was 5 ft., practically at right angles to the axis of the tunnel. The direction of the line of fault is N. 50° W.

In addition to this slip along the fault line, the timbers are broken, and rock and earth caved in from the roof and sides at a number of points.

The next tunnel south, which is 5 720 ft. long, was also badly damaged, the damage, however, being confined entirely to broken timbers and caves from the roof. On the morning of April 18th it was possible to walk through this tunnel, but the minor shocks

PLATE XLII.
PAPERS, AM. SOC. C. E.
MARCH, 1907.
REPORTS OF COMMITTEES ON
SAN FRANCISCO EARTHQUAKE.



MAP OF
SAN FRANCISCO, CALIFORNIA
SHOWING
AREAS WITHIN WHICH SUBSIDENCE OCCURRED
DURING
EARTHQUAKE OF APRIL 18th, 1906.

All subsidences occurred in filled or soft ground. Heavy full lines show clearly defined limits of subsidence and broken lines approximate location where not connectedly traceable. The corner of Eighteenth and Valencia Streets shown thus,- O

that occurred during the day shook down enough material to block it completely at four points, each ranging from 15 to 40 ft. in length. In addition to these four large caves, 150 sets of timbers were broken and scattered throughout the entire length of the tunnel.

The other tunnels along this line, between Glenwood and Santa Cruz, were not damaged to any extent. In one of them one set of timbers was broken, in another, two sets were broken.

Tanks.—Several tanks on the different roads were thrown down. In all cases, however, these were on wooden or cast-iron frames, not braced to stand the twisting motion which accompanied this earthquake. Tanks on riveted frames did not fall, though in several instances they were severely damaged and thrown out of plumb.

Overturned Cars.—At Chittenden Station, on the Southern Pacific, three box-cars, two of them loaded, standing on the side track, were turned over. The track at this point runs N. 51° W., and the cars were turned over to the right side of the track.

On the North Shore (3-ft. gauge), a passenger train consisting of three cars and an engine, standing on the track at Point Reyes, was thrown over on its side, as shown by Fig. 2, Plate XLVII.

A freight train on the Southern Pacific, which was running at the time toward San Francisco, a few miles south of Chittenden, was derailed.

In the mountain region adjoining the line of fault there were a great many slides of earth and loose rock. When these occurred in railroad cuts there was some little delay of traffic, but the actual damage was small.

APPENDIX F.

REPORT OF COMMITTEE ON THE EFFECT OF THE EARTHQUAKE ON HIGHWAY STRUCTURES.

COMMITTEE:
MARSDEN MANSON, C. E. MOORE, E. F. HAAS.

In carrying out the matter of inquiry into damages to highway bridges, letters were written to all County Surveyors in the region affected by the earthquake. Only Alameda County has replied, so far, the reports being "no damage;" all bridges in the county are of non-reinforced concrete from 80 ft. (1) to 60 ft. (2), and then down to 3-ft. culverts. All large bridges have been carefully inspected—not a crack reported in any.



FIG. 1.—LONGITUDINAL DISPLACEMENT ON THE FAULT LINE, AS SHOWN BY A FENCE AT A PLACE INTERSECTING THE PILARCITOS PIPE LINE.



FIG. 2.—DISPLACEMENT OF GROUND AT EIGHTEENTH AND VALENCIA STREETS, SAN FRANCISCO

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PLATE XLIV.
PAPERS, AM. SOC. C. E.
MARCH, 1907.
REPORTS OF COMMITTEES ON
SAN FRANCISCO EARTHQUAKE.

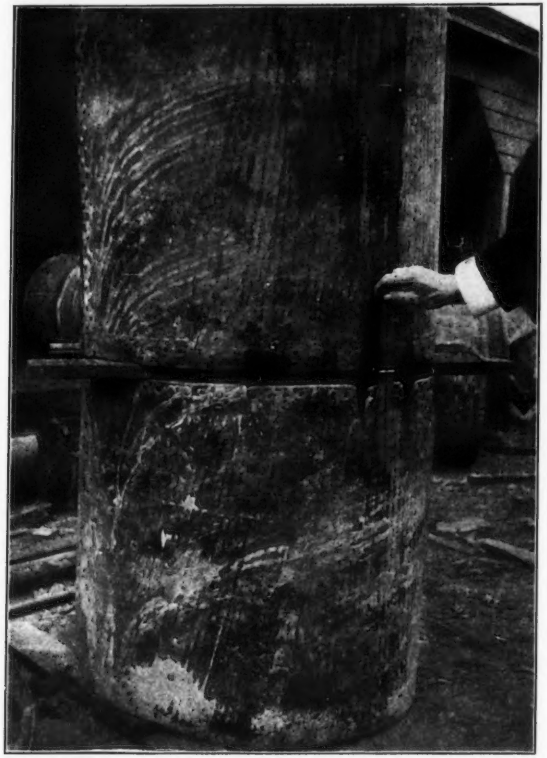


FIG. 1.—SECTIONS FROM A 30-IN. PIPE LINE NEAR ALVARADO, SHOWING CUTS MADE BY THREE SUCCESSIVE EARTHQUAKE SHOCKS.

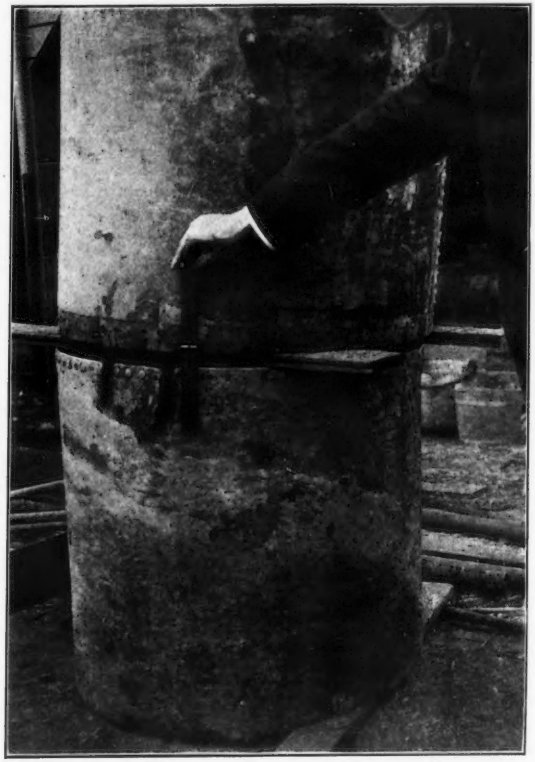
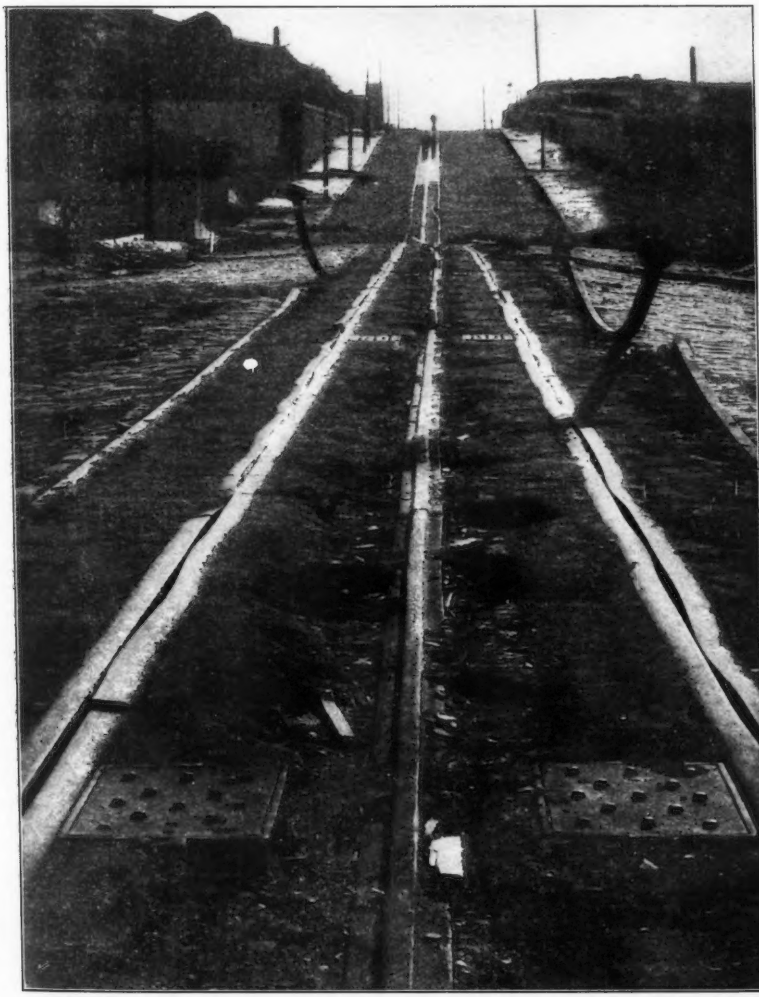


FIG. 2.—OPPOSITE SIDE OF PIPE SECTION SHOWN BY FIG. 1.



CHARACTERISTIC CLOSURE OF CABLE SLOTS IN BURNED DISTRICT OF SAN FRANCISCO. THE VIEW ALSO SHOWS BROKEN CAST-WELD JOINTS, AND EXTREME WARPING OF RAILS.

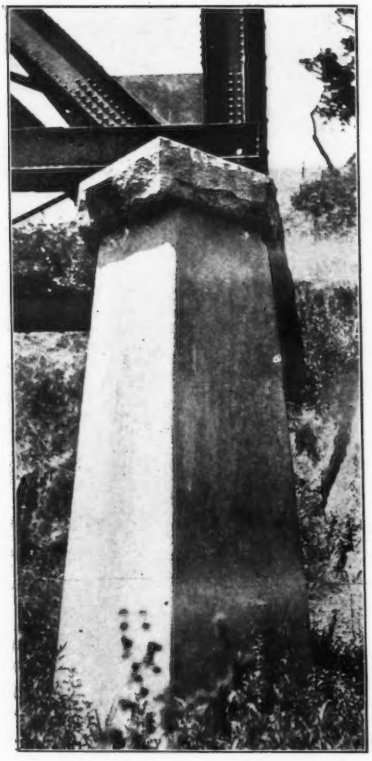


FIG. 1.—PIER 2, PAJARO RIVER BRIDGE.

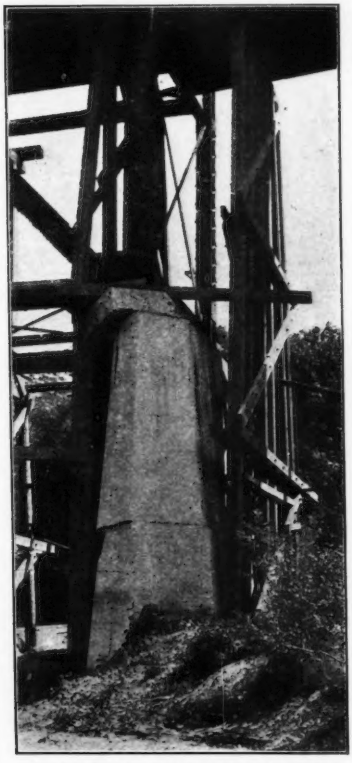


FIG. 2.—PIER 5, PAJARO RIVER BRIDGE.

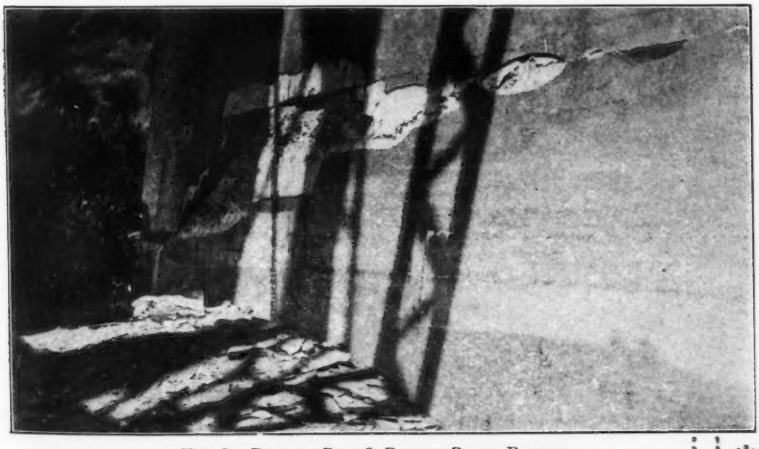


FIG. 3.—BASE OF PIER 3, PAJARO RIVER BRIDGE.

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FIG. 1.—BRIDGE 39, NORTH SHORE RAILWAY, AFTER THE EARTHQUAKE.



FIG. 2.—PASSENGER TRAIN AT PT. REYES, NORTH SHORE RAILWAY, OVERTURNED BY THE EARTHQUAKE.

Vol. XXXIII. MARCH, 1907. No. 3.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

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RAINFALL, AND RUN-OFF IN STORM-WATER SEWERS.

Discussion.*

BY MESSRS. A. MARSTON, W. B. RUGGLES, EMMET A. STEECE AND L. J. LE CONTE.

Mr. Marston.

A. MARSTON, M. AM. SOC. C. E. (by letter).—The most important part of this paper seems to the writer to be the general presentation of the following principles:

First.—The water falling on the so-called "impervious" area of an ordinary sewer water-shed does not all run off as fast as it falls, but part of it accumulates in increasing quantity on the surface during downpours of moderate length, such as cause the maximum discharges from sewer districts of ordinary size.

Second.—As the storm continues at the same rate, the ratio of run-off from the "impervious" area to the rate of rainfall increases, owing to the increased depth and velocity of the surface flow toward the sewer, until finally, if the storm lasts long enough, the rate of run-off from the "impervious" areas becomes equal to 100% of the rate of rainfall.

Third.—The "pervious" area becomes more and more saturated with water as the storm continues, and there will be a percentage of run-off from "pervious" areas increasing from 0 for short storms to quite a large percentage for storms lasting several hours.

There can be no question as to the general truth of these three principles, but when the author attempts to go further and present definite curves and formulas, as in Fig. 8, purporting to show the exact laws of change in the percentage of run-off with relation to

* Continued from February, 1907, *Proceedings*.

Mr. Marston. the time elapsed since the beginning of the storm, the writer believes he is going beyond what the present meager data from gaugings of storm sewers warrant.

These data are not very extensive, and the author himself points out their many defects. For many years engineers have been criticising the old run-off formulas, and new formulas, based on insufficient data, should be avoided.

All that engineers are at present warranted in doing is to make some deduction from 100% run-off from the "impervious" areas, for short storms in favorable cases, and some increase above 0% (say varying up to 20% for 1-hour storms, with average soil and slopes) in the run-off from the "pervious" areas for long storms, both the deduction and the addition being at present left to the judgment of the engineer, in view of his general knowledge and his familiarity with local conditions.

The gaugings shown on Plate CXVIII are of considerable value and interest, though they are not reliable as to relative times of rainfall and sewage flow fluctuations, because the automatic rain gauge was 2 miles away.

The storm of August 21st is especially interesting, on account of the three successive downpours, giving three principal discharge maxima, approximately at 7, 7.30, and 8.30 A. M. These illustrate very clearly the danger of adopting any theory which would make the rate of run-off start in at 0 at the beginning of the downpour which causes the maximum discharge, as indicated by the curves and formulas of Fig. 8.

The fact is that there is always a possibility that at the beginning of the maximum downpour which determines the maximum rate of run-off, an immediately preceding downpour, only a little less in rate, may have already heavily flooded the water-shed, and increased the percentage of run-off from both "impervious" and "pervious" areas. Thus the downpour from 7 to 7.30 A. M., on August 21st, superposed its run-off upon the afterflow of the preceding downpour, and brought the maximum rate of run-off up to approximately 78% of the average rate of the preceding 30-min. rainfall.

This is close to the total percentage of "impervious" area of the sewer district, figured as recommended by Emil Kuichling, M. Am. Soc. C. E., by taking only 80% of the area of first-class pavements.

One is forced to wonder what the discharge of the sewer would have been from the 30-min. downpour from 9.10 to 9.40 A. M., on August 4th, if it had been closely preceded by a heavy downpour, as was the case on August 21st.

The percentage of maximum run-off is also greatly affected by the distribution of the rain through the downpours, as may be seen

by comparing the 30-min. rains of June 26th, and August 4th. The first gave approximately 71%, maximum run-off, and the second only 53½%, the difference being attributable to the fact that the heaviest rainfall occurred at the end of the June 26th, and at the beginning of the August 4th downpours. Mr. Marston.

In regard to the "time of concentration," it seems to the writer that the author is in error in assuming that usually no addition need be made to the time required for flow through the longest sewer to allow for the time required for water to reach the sewer from the gutters and roofs at the most remote point. He argues that this would be balanced by the time required for the water to reach the sewers from the gutters and roofs nearest to the outlet, but this cannot usually be the case, for the increased quantity of water from the surface immediately around the nearest street inlet must usually begin to enter the sewer within 1 min. of the beginning of a heavy downpour preceded by a lighter rain. The curves on Plate CXVIII, which he cites, are not reliable, as regards relative times of rainfall and flow, for the rain gauge was 2 miles away, and he does not state whether the sewer gauge was not some distance from the nearest street inlet.

Alva J. Grover, Assoc. M. Am. Soc. C. E., on Plate IV of his paper "Flood Waves in Sewers, and Their Automatic Measurements,"* presents some simultaneous automatic gaugings of rainfall and sewage flow at Omaha, Nebr., which appear to be perfectly reliable, as regards relative times, and show a practically instantaneous response of the sewer flow to the rainfall.

In regard to new rainfall curves and formulas, it would appear that a number of curves and formulas can be found, all representing the known facts fairly well. The case is similar to that of formulas for safe loads on columns for bridge specifications. In each case the formulas which make the calculations most simple have important advantages over the others. Exponential functions do not appeal to the writer as being convenient for calculations; compare, for example, Talbot's well-known $\frac{105}{T+15}$ with the proposed $\frac{32}{T^{\frac{4}{5}}}$.

The writer has yet to find any general rainfall curves better fitted to published rainfall data, or simpler to use, than Talbot's well-known and simple formulas.

W. B. Ruggles, M. Am. Soc. C. E. (by letter).—The author of this excellent paper quotes the deductions from Mr. Kuichling's experiments: Mr. Ruggles.

"1.—The percentage of rainfall discharged from any given drainage area is nearly constant for heavy rains lasting equal periods of time.

* *Transactions*, Am. Soc. C. E., Vol. XXVIII.

Mr. Ruggles. "2.—This percentage varies directly with the area of impervious surface."

It is not the writer's purpose to dissent from these conclusions as applied to any roof-covered or paved areas—although, even in New York City, 10% of the area upon which Mr. Hering's experiments were made was composed of grass—but to suggest a guard against hasty application of these rules (clearly not intended by the author or experimenter) to drainage districts having areas largely of cultivated lands, or covered with vegetation, especially the dense, heavy-bladed, cup-like vegetation of the tropics, and with a light soil of vegetable mould. Taking as an example the drainage of areas along the Panama Canal, it has been observed that at the end of the dry season, of, say, 4 months, when everything is parched, a rainfall of 3½ in., from 12 to 9 P. M., followed next day by a like amount from 12 to 4 P. M., did not yield nearly so great a run-off at a large pipe opening, readily observed, as would a little more than half as much (during the same time) later in the season when everything was saturated by the daily rains. Even at the latter period, area for area, it would hardly be expected to yield such a run-off as occurred in the Ohio River Valley in the record flood of that stream (which, in 1884, at Cincinnati reached a stage of 71 ft. 0¾ in. above low water) when the rainfall was mainly upon frozen, sleet-covered, but sometimes temporarily thawing, ground, corresponding in condition much more nearly to that of paved areas than could otherwise exist over so large a region. The writer has not at hand the figures for the area or volume of that flood, but, if available, they would probably lend support to the conclusions reached by Mr. Kuichling.

TABLE 7.—Heavy Rainfalls in Cuba, Nicaragua, and Panama.

Place.	Date.	Rainfall, in inches.	Duration of rain.	Remarks.
Santiago, Cuba.....	Sept. 3, 1900...	10.58	12 hours.	Ending 8 P. M. } By U. S. Weather
" "	Sept. 6, 1900...	22.20	60 "	Ending 8 A. M. } Bureau Reports.
Matanzas, Cuba.....	Apr. 6, 1901...	4.7	1½ "	Between 7.30 and 9 P. M.
" "	1901 or 1902*..	6.92	24 "	Almost exactly the same rainfall was reported for Havana on the same day.
Greytown, Nicaragua.	July 18, 1891...	8.17	9 "	
" "	Dec. 5, 1892...	8.75	24 "	
La Boca, Canal Zone..	Nov. 17, 1906...	7.3	24 "	Most of this precipitation occurred in 12 hours.
Culebra, Canal Zone..	Oct. 24, 1890...	4.73	24 "	On the Continental Divide.
" " " ..	Dec. 3, 1906...	5.55	24 "	
Empire, Canal Zone..	Dec. 3, 1906...	6.15	24 "	Of this, 5.6 in. fell in 14 hours.
Culebra, Canal Zone..	May 10-20, 1897.	20.3	10 days.	The total fall for May, 1897, was 32.86 in.

* Memorandum of exact date mislaid.

Mr. Ruggles.

Now that the requirements of sanitation are leading to new or improved sewerage systems in Panama, Cuba, Porto Rico and other tropical countries, more or less under the direction of American engineers, occasion is taken to call attention again to the greater rainfall of those countries, as shown by Table 7.

Mr. Steece.

EMMET A. STEECE, M. AM. SOC. C. E. (by letter).—This problem, so ably handled by the author, is one which engineers have tried to solve in only a desultory way for years, and its importance is worthy of more consideration than it has received.

The writer is of the opinion, however, that a more thorough and systematic investigation of the subject will be necessary before any convenient comprehensive formulas can be written.

The various formulas, including those by the author, contain definite expressions of the slope of the surface, without considering the element of perviousness except by indefinite factors.

In the average impervious district the portion affected by slope is rarely more than 50 per cent. What effect, then, has the slope of the surface upon the remaining 50%, covered by structures of every conceivable shape, and with rain-water conductors of directions as various?

Let it be fully considered that any formula which does not have an arrangement of factors which will make it applicable to different climates is also without material value, for, in the North the entire surface often becomes impervious, as when the ground is saturated and frozen, and in the South the surface conditions change but slightly in comparison.

The writer has made many observations of drain discharge of rainfall, but has not considered them fit for publication for the reason expressed by Mr. Gregory in his comments on some found in engineering literature, namely, their incompleteness.

The writer believes that the best solution of the problem will be accomplished by as complete an investigation as has been given to the properties of engineering materials; fully illustrated by photographic views of the site of each experimental district, rather than formulas based upon a few disconnected individual experiments, widely scattered and vaguely stated.

Mr. Le Conte.

L. J. LE CONTE, M. AM. SOC. C. E. (by letter).—The writer is much impressed by this elaborate paper. The author's collection of data and his criticisms of the various formulas are very interesting. From a sense of duty, however, the writer feels compelled to call attention to the fact that, in his opinion, it is utterly hopeless for anyone to attempt to deduce a useful and practical general formula suitable for application to any case that may come up in practice. It is the writer's opinion that a general formula, which will inspire complete confidence, can never be prepared. This fact is due

Mr. Le Conte. primarily to the large number of entirely independent variable factors necessarily involved in the final result. In all cases like this, the only formula which has any practical value is an empirical one, based simply on facts and observation. Of course, such a formula has naturally a very limited application; and great mistakes are always being made, in trying to stretch it so as to give it a wide field of application. Nothing could be more unfair or irrational, and yet this is being done every day.

The data really needed are more reliable observations and more facts as to the actual maximum discharge of sewers, noting carefully the time interval between the crest of the heavy rainfall and the crest of the maximum sewer discharge following the heavy rainfall.

All the physical facts directly connected with the case should also be noted as fully as possible. When this is done carefully, the results can be used safely, but within narrow limits. The troubles encountered in this problem in hydraulics call to mind the same difficulties in computing the flow and discharge of streams. Nothing is so unsatisfactory to-day, as the various formulas for the flow and discharge of rivers—and yet the variables in those formulas are not nearly as complicated and erratic as those in the storm-water sewer problem.

All the river formulas bear a very close relation to the slope per mile, since gravity is the moving force; but every student of river hydraulics knows that there is nothing so variable and unreliable as surface slope per mile. The channel cross-section is continually changing, the velocity is continually changing, and the slope per mile is also subject to the most erratic changes. The only absolutely constant factor is the discharge, which is uniform. The most remarkable instance, as to slope per mile, is to be noted on the Mississippi River between Red River and Donaldsonville, where there is a stretch of river, extending for at least 40 miles, along which the surface slope is reversed, and is up stream instead of down stream, and yet the great river forges ahead down stream, just as if the slope were in that direction. This instance is only mentioned as a caution to engineers, and to remind them how careful they should be in taking surface slope per mile as a reliable factor. Nothing is more unreliable, and yet all river formulas compel its use as an important factor.

A great many of the older members of this Society, no doubt, have valuable notes bearing upon the subject of this paper, but are chary about putting them in print, because they are a little uncertain about some of the variable factors. The writer thinks this is a great mistake. The more observed facts that can be obtained, the better can the whole category of facts be examined, and in

due course of time engineers will arrive at more intelligent conclusions. Mr. Le Conte.

In the case of Hawksley's original formula, although the rainfall was considered in a general way, yet it is noticed that when he came to frame his formula for practical use he discarded rainfall entirely. As the writer understands it, his original formula contained no rainfall factor. He simply considered the area of the tributary water-shed and the average slopes of the ground surface, and then he carefully gauged the storm-water discharge of the sewers after heavy rainfalls. He also noted the height of the flood wave as it passed the gauging station, and the time length of the same wave, as near as might be. He fully appreciated the fact that it was the shape of this progressive flood wave that he was after, and that this really fixes the proper size of the storm sewer. It may be a long, flat wave, which calls for a comparatively small sewer, or it may be a short, high-crested wave, which calls for a much larger sewer.

By what process of reasoning can one arrive at the conclusion that the rainfall is a direct function of this flood wave? The only direct functions are the physical features of the tributary water-shed. The most that can be made out of the rainfall is a secondary function, and, at all events, it cannot be placed in the same category with the direct physical functions peculiar to the water-shed, which alone influence the shape of the progressive flood wave. Hawksley wisely concluded that, at all events, rainfall is not a direct controlling factor in the problem, and therefore purposely omitted it from his formula. It seems to the writer that this was a logical conclusion.

What engineers wish to ascertain is the actual storm-sewer flow, and this can only be found by actual gaugings. This is far preferable to measuring the rainfall at detached points of observation and then theorizing about, and calculating in the office, the storm-sewer flow from a computed average rainfall over the entire water-shed, which, at best, is the wildest kind of a guess. The thing to observe directly, in any case, is the storm-sewer flow, irrespective of whence or how it really originated.

Of course, rainfall, as a secondary function, has a general bearing on the problem, as instanced by the Brooklyn case, where it became necessary to modify the old formula. In considering this case, it is found that the average annual rainfall at London is only 26 in., well distributed, and with maxima of 1.8 to 2 in. per hour; whereas, at Brooklyn, the average annual rainfall is 43.3 in., and with maxima of probably 3 in. per hour, so that the Hawksley formula had to be modified—but, in any event, the best way to find out definitely how much to modify it, would have been to gauge

Mr. Le Conte. the actual storm flow in existing sewers after heavy rainfalls and note the height and shape of the flood wave passing the gauging station. This is the only rational conclusion. In this way, reliable factors, which could be depended upon in that particular neighborhood, could have been obtained. In applying these results to another city, having markedly different physical conditions, a high order of intelligence and judgment would be required.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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THE DESIGN OF THE NEW CROTON DAM.

Discussion.*

BY MESSRS. CHARLES S. GOWEN, GEORGE L. DILLMAN AND LUTHER WAGONER.

Mr. Gowen.

CHARLES S. GOWEN, M. AM. SOC. C. E.—Mr. Wegmann's paper is comprehensive, in so far as it relates to the history of the design of the New Croton Dam, and to the account of the mathematical work involved, and is of value as showing in detail the methods used in the calculations of the theoretical profile of the dam section, and in its references to certain practical questions involved in the design of such a structure.

In a sense it completes the records in the *Transactions* of this Society as to the planning and construction of an unprecedented and notable engineering work.

The literature referring to this design, however, is not lacking, but is embodied in the various reports of the Aqueduct Commissioners, which have been referred to and quoted by the author. These reports deal very fully with all the points involved in connection with the design of the Quaker Bridge Dam profile as finally adopted by the Aqueduct Commissioners' engineers, as well as with the profile recommended by the special board appointed to consider the question. However, as these reports are not generally available to the profession and the public, Mr. Wegmann's paper may be considered as especially valuable, both as a matter of record and as a matter of information.

* This discussion (of the paper by Edward Wegmann, M. Am. Soc. C. E., printed in *Proceedings* for January, 1907), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Gowen.

The design finally adopted by Mr. Fteley for the New Croton Dam section was, as stated by the author, the Quaker Bridge section slightly modified. The results derived from the study which resulted in the Quaker Bridge profile were considered final and conclusive, as might be expected, the change of location involving no questions of theory and consequent additional research. The speaker was somewhat familiar with this question at the time the contract drawings were being made, and recalls that the calculations of pressures were examined in view of the possible changes in the weight of masonry that might be used in the dam construction.

As to the author's criticisms of the profile adopted, the speaker, in reviewing them, is disposed to take exception to them as follows:

First.—As to the statement that in the Quaker Bridge profile the maximum pressures at a depth of 110 ft. were assumed to be 10 400 lb. per sq. ft. and 20 625 lb. per sq. ft. for the down-stream and up-stream faces, respectively. In Table 2, for the theoretical profile, as quoted by the author, the calculated pressures are 16 391 and 17 453 lb. per sq. ft. for the down-stream and up-stream faces, respectively, while in Table 3 the calculated pressures in the adopted profile are correspondingly 16 217 and 17 544 lb. per sq. ft.

Tables 2 and 3 show, as the author states, greater pressures on the up-stream than on the down-stream face for a depth which ranges from 110 to 231 ft. in Table 2, but it will be noted that the pressures at a depth of 110 ft. at the two faces do not vary very materially, although the pressure on the up-stream side is somewhat greater. It seems to the speaker that it is to be assumed that the ultimate up-stream face pressures should be limited in the same way as those on the down-stream face; hence the 30 000-lb. per sq. ft. limit, as shown in Table 2. This limit is somewhat increased in Table 3 owing probably to cutting off the down-stream toe, which, as the author observes, has increased the calculated pressures at that point. The increase in the toe limits, as shown by Table 3, is not significant, in view of the generally admitted proposition that the toe pressures at the base of such a profile are less by a considerable amount than those calculated. It is well known that such an actual condition results in errors on the side of safety when profiles are calculated on theoretical lines, and, through this condition, the cutting off of the down-stream toe, as shown in the profile, and to which the author objects, would seem to be justified, even if the practical consideration that masonry at the extreme end of such a toe would not have mass or strength sufficient to be effective, be ignored. This contention, that the toe should have remained, seems to be based on the assumption that the line of pressure at the down-stream face is parallel to the face of the dam, and Mr. Wegmann states that experiments lately conducted tend to prove this.

That such a condition has for a long time been assumed is evident, as certain high masonry dams in Europe and America, built since the determination of the New Croton Dam section, were planned to have selected stones approximately rectangular laid on inclined beds which approach the normal to the profile inclination near the toe. While, in the speaker's opinion, it is a question as to whether the extra expense involved in such construction warrants the results obtained, there is certainly no disposition on Mr. Gowen.

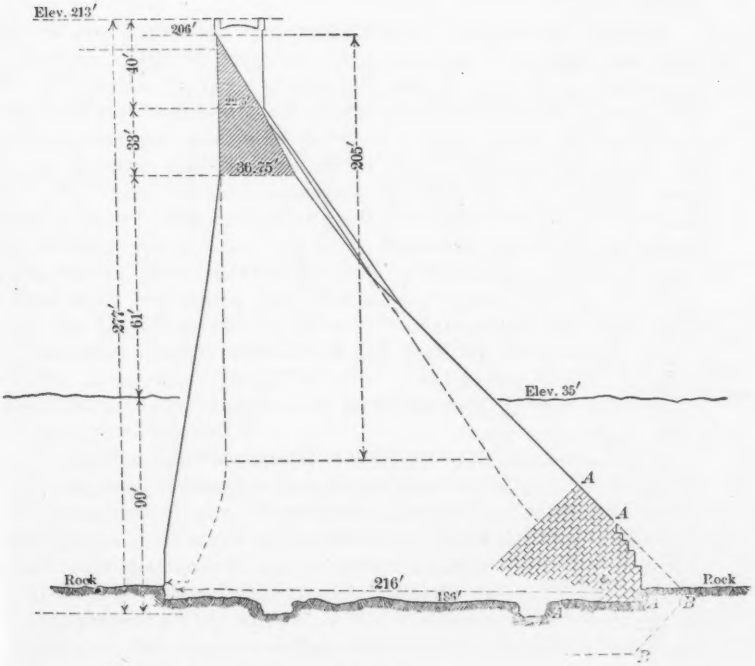


FIG. 10.

his part to criticise the possible effectiveness of such an arrangement of the masonry. But that such arrangement warrants or necessitates the carrying of the toe to the rock bottom, in accordance with the theoretical lines, does not appear, and certainly the toe thus carried out in its outline could only be effective if sufficient excavation were made in the foundation rock to afford an adequately extended skewback, such as is always provided in arch construction. Fig. 10 may illustrate the speaker's point more clearly than the text.

Mr. Gowen. In the case of the New Croton Dam, *A A A A* shows the curtailed toe and the lines of the rock foundation below, certainly it would seem that, if the toe were left in, to accord with the author's idea, a special excavation in the rock bottom approximating the lines, *A B B B*, would have to be made, in order to render the small retained triangle of masonry effective. It does not seem to the speaker that such work is called for, particularly when it is shown that toe pressures with the toe abbreviated cannot be excessive and are, as is generally admitted, less than the calculations shown.

Second.—As to the author's contention that there was an arbitrary assumption of toe pressures at a depth of 110 ft. and that it was illogical in view of this and of the gradual increase of pressures below the 110 ft. depth, not to have designed the upper part of the profile solely with a view of confining the pressure lines just within the middle third of the section, and then to have allowed a gradual increase of pressures until a maximum limit should have been reached and the profile continued below with this maximum limit not exceeded, it would seem to the speaker that these conditions, practically, were all kept in mind in the design of the theoretical profile, as the following points had to be kept in view from the beginning:

(*a*) The top of the dam had to be of a certain thickness, say 20 ft., to afford a roadway.

(*b*) The top of the dam had to be built at a certain height above high-water mark.

(*c*) It was essential that lines defining slopes and batters of the profile should show easy and gradual changes from the vertical, in order that the gradually cumulative pressures resulting from the elevation of the water behind the dam might be properly transmitted to the base without undue strain at any particular point. This point was dwelt upon particularly in Mr. Fteley's report on the Quaker Bridge profile, and it is this that accounts for the up-stream pressures between the depths 110 and 258, in Table 3, which are criticized by the author as being higher than on the corresponding lines on the down-stream face. It is this consideration, also, taken in connection with the surplus of section and weight due to the necessary height of the dam and the planned roadway, which results in the somewhat narrow limit between the pressure lines in the middle third at a depth of 110 ft., and the resulting pressures at the joint ends, of about 17 000 lb. per sq. ft., which, while they may be less than theoretically allowable, are not inconsistent as between the up-stream and down-stream faces, while they are certainly moderate. Different assumptions in calculating the theoretical profile, made in accordance with the author's expressed ideas, would have resulted in sharper angles in definition

of the up-stream batter below the 110-ft. depth, and the same would have been the case with the outline of the down-stream face, which would have shown too marked an angle between the upper and lower sections. Mr. Gowen.

In fact, in the speaker's opinion, the contention that the profile is consistent can be easily sustained by an inspection of the calculated factors of safety against overturning, due to the profile as adopted in Table 3.

These are as given in Table 4.

TABLE 4.

Depth of water, in feet.	Factor of safety.	Depth of water, in feet.	Factor of safety.	Depth of water, in feet.	Factor of safety.
66	2.07	132	2.38	198	2.99
77	2.09	143	2.49	209	3.10
88	2.10	154	2.60	220	3.22
99	2.12	165	2.69	231	3.29
110	2.15	176	2.79	243	3.33
121	2.27	187	2.88	258	3.29

As Mr. Wegmann's contentions are based upon certain assumptions regarding pressures and the resulting consequences, and not upon methods of derivation and calculation, it would seem that Table 4 shows that such assumptions as were made gave consistent and logical results.

Third.—Mr. Wegmann states that it would have been better if the contract drawings had shown a compound curve to define the upper part of the down-stream face instead of the right lines used, which were later modified in construction by curves joined with short tangents. In reply to this, it may be said that the contract drawings showed definitely and properly the section planned, and the curves substituted later were simply to smooth the general effect of the face, and the tangents joining these curves are not discernible.

Fourth.—As to the author's statement that a profile could easily have been designed with the up-stream face vertical, and that this face could have been continued to a depth of 200 ft. before reaching a pressure of 30 000 lb. per sq. ft., and that such a face would have been preferable on account of simplicity of construction, it must not be forgotten that in the building of the dam there was a depth of nearly 300 ft. to be provided for, and that the necessary batter below 200 ft. to provide for the increase of section required would be too great, for the reasons given above.

Finally, as to the contention that the dam should have been built at Quaker Bridge, it may be said that this site was carefully

Mr. Gowen. investigated and finally rejected, as it was deemed that the abutting hillside at the north end was not adequate to stand the pressures and probable leakage that would obtain. The Cornell site was not ideal, nor desirable, and was not recommended by Mr. Fteley as Chief Engineer of the Aqueduct Commission, when its construction was decided upon. The dam, however, has been built and is serving its purpose, and it would be a difficult matter to prove that the site on the whole is inferior to the original Quaker Bridge location.

In presenting his paper, Mr. Wegmann referred to the extended and prolonged foundation work at the New Croton Dam site as one of the reasons why the Quaker Bridge site would have been preferable. This reference is misleading, and for the following reasons:

The foundation conditions, as developed according to the original plans, proved to be as anticipated when the work was begun, and were dealt with adequately. The drastic change by which the masonry section was extended into the side hill, involved a very large increase in foundation work and expense, which was not anticipated by the people who advocated and insisted upon the change. The speaker feels free to say that this change was unnecessary and resulted only in loss of time and in undue expense, and he certainly cannot concede that the conditions thus developed are of any weight in support of the original Quaker Bridge site.

Mr. Dillman. GEORGE L. DILLMAN, M. AM. SOC. C. E. (by letter).—The writer would call attention to the fallacy in argument by all masonry dam analysts who have developed or adopted uniform section types. Their argument (expressed or implied) is that because a uniform construction of a safe profile insures stability, uniformity is necessary to stability. This is not only not so, but the type suggested by the writer some years ago of a buttressed wall is more stable than any uniform section type, and incidentally contains considerably less masonry.

The Croton Dam is a great structure. The writer has no doubt of its stability; but a finer structure, architecturally, and a safer structure, against ordinary failure or earthquake effects, could have been built at materially less cost as a buttressed wall.

It is time the engineering profession cast off the fetters of antiquity and ceased to be bound by tradition. De Sazilly took a great step in advance. Rankine did great work in his various analyses. Engineers can study their work with profit, yet need not unquestioningly follow them. Analysts since their time have only refined their methods, whether with improvement being a matter of opinion.

Mr. Dillman.

Another thing: Masonry is more or less permeable. In the mathematics of Mr. Wegmann's analysis it is presumed that the upper face is tight. Suppose it is not. For the sake of safety, presume the tight surface to be one-half or three-quarters of the distance to the down-stream face. Where does all this analysis lead? It proves the dam to be absolutely unsafe. In one case the line of pressure (reservoir full) falls outside the middle third. In the other case the factor against overturning is less than one. The attempt to make a dam tight from face to face is a mistake. If the upper face is tight it will do no harm. But if the upper face is not tight and water is stopped at some other place, tightness at the second place is an element of weakness, and may be fatal.

The foregoing hypothesis is perfectly possible. The masonry may be permeable to some point below the up-stream face; it may be permeable to near the down-stream face. In the former case, the dam is less safe than the analysis shows. In the latter, a rational analysis would prove the dam absolutely unsafe.

Such a result could not obtain with the buttressed-wall type. In case of permeability, the factor of safety against overturning would be reduced, but never to less than 1, and the line of pressure would not be outside the middle third (reservoir full).

Mr. Wagoner.

LUTHER WAGONER, M. AM. SOC. C. E. (by letter).—The historical part of this excellent paper, such as changes of plan, boards of experts, with attendant delays, reminds one of the struggle with the water problem in San Francisco during the past 30 years. The Croton Dam (a municipally owned and managed one) was discussed for about 10 years, and was constructed in the next 14 years; thus in 24 years, with ample engineering talent and plenty of money, New York has a completed dam; while San Francisco has advanced no further than the preliminary or talking stage, and the present average mental condition is that a new water supply is needed, but public opinion is still unformed as to how, when and where, it is to be obtained.

Persons interested in municipal ownership, *pro* and *con,* can read Mr. Wegmann's paper with profit.

The writer has read with much interest the reasons given for building a straight dam instead of a curved dam, as advised by the Board of Experts in 1888. One of the reasons given—that curvature might set up dangerous strains—deserves a passing notice, and, in the writer's opinion, this is due to the author's application of the hoop tension formula to the case of curved dams. In this formula,

$$T = pr$$

Where T = the uniform thrust in a circular ring,
p = the pressure per unit of length of the ring,
r = the radius of the ring's outer surface.

Mr. Wagoner.

While this formula is true as regards an external force such as would collapse a tube, it certainly does not apply correctly to dams, either curved or straight, for in the latter case, r, the radius, is infinite, hence the thrust, T, is infinite. But, as straight dams exist, and as it is also certain that they are not acted upon by infinitely great forces, it should be clear that the formula in question does not apply correctly. To hold that it does apply to curved dams, suggests the old problem of an irresistible force meeting an immovable body.

Another objection is urged against curvature, that it increases the quantity of masonry without any beneficial result. On page 30* the author states that with approximate dimensions of radius 1 200 ft. and a crest length of 1 350 ft., there would have been an increase of volume of masonry of about 10 per cent. This corresponds to a central angle of about 65 degrees. Within the limits of any useful curvature for curved dams, the excess of length of arc over chord varies as the square of the arc, or the percentage of excess of the arc over the chord $= 0.00131^2$, in degrees, which, for 65°, is about 5.5%, but, at the center there is no increase, and it should be remembered that the major portion of the volume is ordinarily embraced by smaller angles than the crest. Taking the section used, and combining it with the profile in Mr. Gowen's paper, it appears that the foregoing curvature would have added about 2.8% to the volume.

Within the limits of useful curvature, it may be said that the increase in volume varies from 1¼ to 3%, depending upon the cross-section of the valley.

In collaboration with Mr. Hubert Vischer, the writer studied the Bear Valley Dam, and the results were published under the title "On the Strains in Curved Masonry Dams."†

In this paper some notice is taken of the author's hoop compression theory previously mentioned. As to the further reason given for avoiding curvature—on account of the difficulty or rather impossibility of computing the stresses—the writer believes that in the paper on the Bear Valley Dam by Mr. Vischer and himself, methods of computation of such stresses have been set forth with sufficient clearness to give an approximate solution of such questions as may arise in practice. In that paper it has been shown, for the Bear Valley Dam, that the moment at the lower toe is reduced about 20%, this relief being due to arch action, while the increase in the volume of masonry is not much in excess of 1 per cent.

Elsewhere in that paper it is shown that much greater economies would have resulted from a better selection of radius and profile.

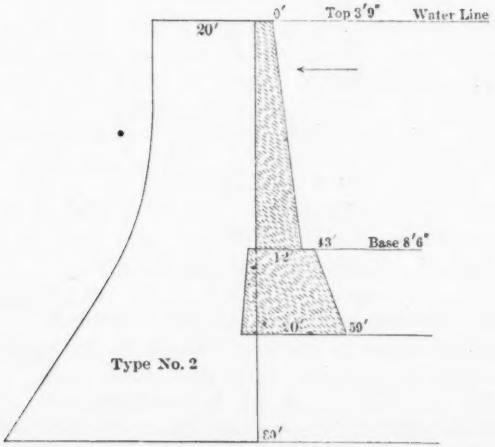
* *Proceedings*, Am. Soc. C. E., for January, 1907.

† *Proceedings*, Technical Society of the Pacific Coast, December, 1889.

Mr. Wagoner.

On page 24* of Mr. Wegmann's paper it is stated that the Bear Valley Dam, built in 1884 has been replaced by a stronger one; this is an error, as the original dam is still in use. Some slight work has been done about 50 ft. down the stream for the foundations of a new dam, but it in no manner relates to the original work, which is apparently in good condition to-day, after 23 years of use.

As a matter of interest, Fig. 11 is introduced, the left-hand part being Mr. Wegmann's Practical Profile Type No. 2 to a depth of 80 ft., and the right-hand shaded figure being the profile



COMPARATIVE PROFILES OF MR. WEGMANN'S TYPE NO. 2. AND THE BEAR VALLEY DAM.

FIG. 11.

of the Bear Valley Dam. The writer does not offer it as an example of good practice, but only as confirmatory of his final remarks about the necessity for a revision of current ideas about permissible unit stresses.

Arch action is always worth much more than its cost in volume of masonry, for by its use the strain upon the lower toe can be relieved, and this in turn is sufficient warrant for some reduction in the cross-section of the dam.

Aside from æsthetic considerations, it also provides for automatic relief from stresses due to temperature changes, and renders a dam safe against ice thrust and wave action, and probably all but the most severe earthquakes.

* *Proceedings*, Am. Soc. C. E., for January, 1907.

Mr. Wagoner.

As an illustration, take the case of the Austin Dam. Had this dam (a long, low one) been arched, perhaps to a central angle of not more than 30°, involving about 1% increase in the volume of masonry, there can be no reasonable doubt that, even had it cracked under the sudden load due to the flood, its parts could not have been overturned, or pushed bodily by sliding down stream, as occurred.

The writer, being a known advocate of curvature for masonry dams, has been criticised for the use of both a gravity section and curvature in his design for the La Grange Dam, but, in that case, the conditions were different. The water-shed above the dam is 1 500 sq. miles, and the high-water mark of the flood of 1862 was found near the dam site, and at several points above it, from which it was computed that 130 000 cu. ft. per sec. might have to pass over the crest, and fall 110 ft. Such a flood would make about 19 ft. of water over the crest. The plans were competitive, and it was known that the consulting engineers did not regard favorably any reduction from a gravity section. The owners desired security against any accident, and it appeared that the possible loss due to a failure of the dam might be a thousand fold more than the cost of extra volume due to curvature. Any one of the above reasons are deemed sufficient answer for the choice.

The methods of computation set forth by Mr. Wegmann will be of convenience to the profession, as far as methods of procedure go, but it has long been in the mind of the writer that too much weight is attached to precedent as to permissible loads.

Reading Mr. Gowen's paper, which carefully sets forth in detail the methods used in setting the stone in the New Croton Dam, it would appear to be entirely possible that there is a factor of safety of from 10 to 15 for any possible load.

How long shall engineers continue to worship the "Sacred Cow," or permissible loading of about 200 lb. per sq. in. for good solid masonry?

In structures of concrete, twice this value is recognized as good practice. For the nearly constant and quiescent load upon a dam, is there any good reason why a lower factor of safety could not be used?

This is a very important subject for those who plan dams, because in many cases it is the extra height gained that determines the storage capacity. Many new engineering projects might become possibilities if higher unit loading was allowed. Finally, does not the whole subject of permissible loads upon first-class masonry require revision?

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

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PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

UNIFORMITY OF REQUIREMENT AND CLEARNESS OF SPECIFICATION IN AGREEMENTS FOR THE GRADUATION OF RAILROADS.

Discussion.*

BY MESSRS. GEORGE L. DILLMAN, J. L. CAMPBELL, M. S. PARKER, HALBERT P. GILLETTE AND JAMES H. KENNEDY.

Mr. Dillman.

GEORGE L. DILLMAN, M. AM. SOC. C. E. (by letter).—Many of the objections by Mr. Dennis to modern railroad grading contracts are well taken.

Regarding classification, the writer has worked under specifications with from two to eleven classifications. It is his opinion that three classes are better than two, or four, or more. As to the defining clauses, it is hardly material to the contractor what they are, if he knows what they are when making his prices. It it much more important to know who will make the rulings.

The following definitions are suggested as being in line with recent practice:

"Solid Rock" shall include all rock, in ledges or masses of more than 1 cu. yd., which requires blasting.

"Loose Rock" shall include all detached masses of rock measuring more than 1 cu. ft. and less than 1 cu. yd.; also, all shale, slate, soft sandstone and hardpan which can be removed with bar and pick, though blasting may be resorted to.

* This discussion (of the paper by W. F. Dennis, M. Am. Soc. C. E., printed in *Proceedings* for January, 1907), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Dillman.

"Earth" shall include all material not classed above as solid or loose rock.

The plow test never appealed to the writer as a proper test at all. He has seen ten mules stretched out and pretending to pull hard, but not pulling a pound. He has seen solid rock in ledges torn loose with a plow, not exactly plowed, but loosened cheaply in that way. The ordinary engineer is not a mule expert, to know whether or not the animals are pulling.

With foundation excavation, no specification applies to two connective cases. Such work is usually taken out, or at least trimmed up, under the direction of an inspector working under orders; and cost plus a percentage is the only way to eliminate hazard to the contractor or excessive cost to the company. At the letting of a contract, seldom have the investigations proceeded to such a point that a price per unit, or any other way, would represent cost plus a fair profit.

The author is certainly right in cutting out the useless refinement of the prismoidal formula. If a contractor gets his banks full and his cuts of full width, he has done many times as much work outside of the computed prisms as he is paid for by the error of end-area computations.

Overhaul, with a specified free haul, was originally an attempt to even up the cost of grading, the haul being unequal. Beyond a 300-ft. free haul, the writer is of the opinion that it does not serve its purpose, and, when the free haul is extended to 800 or 1 000 ft., it is absolutely pernicious. On the other hand, there seems to be no reason for paying the same for train haul in steam-shovel work as for team or light-car haul. If the method of working is understood in a general way, it will be fair to pay for team haul per 100 ft. and train haul per mile, per cubic yard.

There is certainly no justice in making a contractor pay for work by forcing the haul clause to save right of way. Each case should be considered by itself, and the rule should be applied so that the total economy should be greatest; *i. e.*, the cost of the adjacent right of way plus cost of short haul should be placed against the cost of distant right of way plus long haul. The fact that the company paid one item and the contractor had to pay for the other should not affect the decision of the engineer.

The writer sees no objection to the clause regarding sub-contractors. It is used in order to have only one party with whom to deal in a legal sense, so that, in case of differences, there will be fewer parties to the controversy. In operation, it is never abused. Building contracts are not similar. The various lien laws require certain published statements, sometimes the contracts in full, which would be inexpedient in railroad contracts, and more obnoxious to the contractor than the company.

Mr. Dillman.

The writer does not agree that the engineer has too much authority. It is true that in a few cases such authority has been abused, for human nature varies; but, put the authority with the contractor and see where railroad contracts would end.

The object of a contract is to get work done. For its execution, the contractor is one tool, the engineer another. Authority must be given to one or both of them. A divided authority is never efficient. In the interest of ideal fairness, this authority might be divided, but in the direction of attaining the desired end, full authority should be left just where it is. Responsibility is fixed by it, and could be in no other way.

The author has left out the matter of shrinkage. Of course, some material will shrink in banks, and this fact should be reckoned with in grading. The question is, who should pay for it? A clause by which the contractor agrees to put on shrinkage up to 10%, if required by the engineer, makes a straight difference of 10% to the contractor, depending on whether the engineer does or does not order it. This 10%, gross, may mean doubling his profits, or making a losing contract, as the case may be.

Where practicable, quantities paid for should be measured in excavation. Where it is not practicable to measure them in this way, and the payments are made on bank measurements, the writer suggests that extra material, put on for anticipated shrinkage, be paid for at the same price as other yardage.

A contractor objects when shrinkage is first demanded, objects when it is enforced, and may get so used to it that he quits objecting; but he never gets over the fact that the requirement is unfair, as, in fact, it is. Like an abnormal free haul, it is an attempt on the part of the company to get something for nothing, which, in time, reacts.

The writer, however, fully agrees that uniformity in grading specifications is desirable, and, while not agreeing with some of the details suggested, admits that uniformity, with some bad details, is better than the present lack of it.

Mr. Campbell.

J. L. CAMPBELL, M. AM. SOC. C. E. (by letter).—The writer believes that the prevailing classification of earth, loose rock, solid rock, and overhaul should be eliminated, and that part of the work should be covered by a single unit price per cubic yard.

If a classification is to be retained, the writer suggests the desirability of eliminating the terms, "earth," "loose rock," and "solid rock," and substituting therefor the designations, Class 1, Class 2, and Class 3, and making the specifications read somewhat like this:

Class 1 shall include all material which can be broken and loosened by a standard No. 1 railroad plow into a condition in which it can be removed by standard railroad scrapers, the plow

Mr. Campbell. and the scrapers being drawn by power sufficient to develop their full capacities.

Class 2 shall include all material which cannot be broken and removed as specified for Class 1, but which can be loosened and removed by picks and bars, or by a standard steam shovel, rated at 50 tons or more, and without the use of explosives.

Class 3 shall include all material which cannot be removed without being broken and loosened by the use of explosives.

The mere use of the means specified for Classes 2 and 3 will not of itself be evidence of, nor shall it necessarily fix, the classification of the material, because the contractor will frequently find it to his advantage and will use the means prescribed for the higher class to remove material of the lower class. It must be shown that the means used are actually necessary for the removal of the material in question, and, in case of doubt or question about the class of material, the company's engineer shall require, and the contractor, under the direction of said engineer, shall make, such conclusive tests as will determine the class to which such material belongs. Whenever possible, such tests of such material shall be made before the latter is removed.

The writer suggests this, not as a perfect specification, but merely as a change in the right direction. The terms, "earth," "loose rock," and "solid rock," may be entirely misleading as a specification, for each may, and frequently does, include a great variety of material which, in the abstract, is neither earth, loose rock, nor solid rock.

The customary overhaul clause should be omitted, either with or without a classification.

Mr. Parker. M. S. PARKER, M. AM. SOC. C. E. (by letter).—Mr. Dennis strikes a popular chord when, in the conclusion of his most seasonable paper, he says:

"There is no valid reason why the agreements should not be standardized. The consideration and preparation of a standard form would be a very useful and important work for this Society."

The writer, having had many years of experience, both as an engineer and as a contractor, heartily concurs in this sentiment. The specifications now in use on many of the great railroad systems of America are as old as the systems themselves. They are old forms, handed down from generation to generation, with an occasional new feature added. It matters not that many clauses may have been ruled against by the courts, the same clauses still appear, either in the hope that they may "stick" in some particular case, with benefit to the company, or from absolutely careless disregard of the rights of the contractor. The author has made a strong argument in favor of standardizing railroad grading specifi-

Mr. Parker.

cations, and it seems to be almost unnecessary to add more on this subject. All must admit the desirability of united action toward such uniformity. The railroads of America are expending more money yearly in construction than all other industries combined. When such men as J. J. Hill, F. Am. Soc. C. E., President of the Great Northern Railroad, estimate that, under the present conditions of traffic, there is needed on the railways of the country an expenditure of $5 500 000 000 within the next five years, some idea of the enormous extent of the railroad contracting interests can be obtained.

Many of the clauses in the specifications for grading on large railroad systems are meaningless, and have no legitimate place there. Were these clauses to be enforced, no reputable contractor would consider for a moment the advisability of taking the work offered. All the specifications of the various railroad systems are similar in many respects; clauses regarding the subletting of work; the infallibility of the engineer in all decisions, whether right or wrong, as clearly outlined by the author, and many other dead-letter clauses. Why should not the position of the engineer, as judge, be defined in some more rational manner? Why not substitute such a clause as the following?

The decision of the engineer, on any point or matter touching this agreement, shall be final and conclusive during the progress of the work. This, however, shall not deprive the contractor of any of his rights of redress in case such decisions are palpably wrong in intent or through ignorance of the facts.

Engineers, as a rule, are inclined to be just and fair in their judgment, but they are not infallible. They are subject to error, as are other mortals.

The *bête noir* of contractors on railroad grading work, and also a source of great annoyance to engineers, is classification and overhaul. Engineers vary in opinion as to the proper classification of material under the different specifications, and, to the contractor, overhaul, as calculated by the various methods, is an indefinite quantity.

Clauses in specifications governing the classification of material cannot be expressed too carefully. The terms, "earth," "loose rock," and "solid rock," are a source of much juggling when one indulges in recourse to the courts. The writer has long held the opinion that these terms, used so generally in railroad specifications, should be eliminated, and "classes of material" substituted, the material constituting each class being clearly defined. This method has been adopted by the United States Government in its grading specifications, and railroads might well follow the example, and avoid all complicated technical misunderstanding of words.

Mr. Parker. The terms, "earth," "loose rock," and "solid rock," in themselves, do not express the character of the material to be moved, and the explanations following them in specifications do not change the fact. To designate as loose rock such material as cemented gravel, hardpan, soft sandstone, soapstone and disintegrated granite (which can only be disintegrated through the process of blasting) is absurd.

Solid rock, defined as "rock in solid beds or masses which can best be removed by blasting," would appear to cover the ground intended by the term "solid rock." Such a definition, however, followed by a stipulation that it must ring under the hammer, is ridiculous. This clause, appended to a "solid rock" provision, would place solid sandstone and certain other formations of solid rock in the "loose rock" class, instead of in the "solid rock" class where they rightfully belong. Disintegrated granite boulders, after long exposure to the weather, become so hard that tools will barely cut them. They will ring under the hammer, but a little dynamite will shatter them so that they can be handled as gravel. Solid granite formations which can only be disintegrated by blasting should be classed as solid rock.

The following classification is suggested as fully covering the subject, where three classes are provided:

Class 1.—All rock in solid beds or masses which can best be removed by blasting.

Class 2.—Slate, shale, hardpan, cemented gravel, soapstone, soft sandstone, and all other rock loose enough to be removed without blasting, although, to facilitate handling, blasting may occasionally be resorted to.

Class 3.—All material which in its natural condition can be plowed with a plow cutting a furrow 10 in. wide and 10 in. deep, drawn by four horses or mules, each weighing not less than 1 100 lb., and moving at a reasonable plow speed.

Where any excavation contains material of more than one classification, the relative percentage of each class shall be determined by actual measurement and observation during the progress of the work.

If this last clause is observed by the engineer, the classification will not be so much a matter of opinion as is too often the case under present practice. It is folly to attempt to classify, with any degree of fairness, any excavation containing the various classes of material, after the excavation has been made. This method, so often followed, is unfair to both parties. It resolves itself into a guess as to classification, and the question as to who gets the best of it depends on the guessing ability of the engineer.

The writer has in mind an instance of the varying opinions

of engineers as to classification: A cut containing 20 000 cu. yd. was divided in the middle on two engineers' divisions, each getting 10 000 cu. yd. The cut was uniform in depth on both sides of the dividing line. The character of the material was the same throughout the cut, and was hard sandstone overlaid with a layer of earth too thin to be removed by plowing and scraping. The entire cut had to be blasted continually. One engineer turned in his final estimate of 9 500 cu. yd. of solid rock and 500 cu. yd. of earth; the other estimated 500 cu. yd. of earth, 3 500 cu. yd. of loose rock and 6 000 cu. yd. of solid rock. This is one of many instances which the writer could give, which show clearly a difference of opinion in matters of classification, where no difference should be possible. Mr. Parker.

For moving classified material at mean fair prices a contractor may make a reasonable profit on his work, or he may lose money, depending entirely on the judgment or opinion of the engineer; and, under many specifications, there is so much room for error in opinion that a contractor never knows how he is to fare in the final settlement. This condition should not exist. In the writer's opinion, the fairest and most reasonable grading specifications divide the material into two classes: solid rock, or material of the first class; and earth, or material of the second class, which covers all other materials. The work should be paid for in embankment and also in excavation, or "pay both ways," as it is usually termed. Eliminate the overhaul provision and make the extreme haul 2 000 ft., with a special price per cubic yard for any haul of more than that distance. A contract drawn on these lines prevents all controversies between engineers and contractors in reference to classification and overhaul, much to the relief of both parties.

The overhaul provision in specifications is a source of never-ending controversy. In the early days of this provision, overhaul was largely a matter of guess, as with classification, especially with railroad building in the West. The writer is familiar with many methods of calculating overhaul. Many of the graphical methods are so obscured in mathematical detail that, to the average grading contractor, they are absolutely unintelligible.

The method now used extensively is to take the distance between the centers of mass in excavation and embankment for the average haul, and deduct therefrom the free haul. This, when used properly, appears to be about as reasonable a method as can be devised.

All methods of calculating overhaul known to the writer are erroneous to a greater or less degree. Ordinarily, no consideration is given to the shrinkage or swell of material from excavation. It is assumed that a certain number of cubic yards of

Mr. Parker. excavation in place will make the same number of cubic yards of embankment. The error is evident. For example, 10 000 cu. yd. of earth are hauled from a cut to make 10 000 cu. yd. in an embankment upon which the overhaul has been calculated. The excavation falls short of making the embankment by 1 000 cu. yd. The contractor is paid for the overhaul as calculated and puts in the extra 1 000 cu. yd. at his own expense, or, rather, receives the overhaul price instead of the embankment price for the extra 1 000 cu. yd. Such instances are common, and have come under the writer's observation frequently; they are not exceptions.

In the excavation of rock formations, the swell of the material varies greatly, depending upon the class. When, from an excavation, the embankment quantities are made and the extreme limit of haul is reached, the remainder of the excavation must be wasted. The contractor receives pay for overhaul for the yardage in the embankment; but, for the waste material, he receives no compensation for hauling, unless he elects to haul past the haul limit and accept embankment price for it. As a result, he often hauls from an excavation a large percentage of the material without any compensation for such haul. In many cases this waste material must be distributed along the embankment, and this becomes an unjust burden on the contractor. In the writer's experience, no instance is recalled where the length of overhaul has been calculated on the route taken from cut to fill. The writer has in mind several instances of 100-ft. cuts into 100-ft. fills, as mentioned by the author. Some were filled from suspension bridges, and others by using a long and elaborate system of tracks and trestles. In such cases the ordinary allowance per cubic yard for overhaul does not begin to cover the expense of hauling, and, as a matter of fact, from the writer's experience, the average price of 1½ cents per cu. yd., paid for overhaul of more than 500 ft. and up to 1 500 ft., rarely pays for the expense of hauling, under the most favorable circumstances. Under the method of estimating overhaul from center of mass to center of mass, the writer has known instances where the engineers construed these centers as being the limit of haul. Under a clause in a contract limiting the haul to 1 500 ft., the writer has hauled material for twice this distance, or until the centers of mass were 1 500 ft. apart. If the overhaul clause is to remain a part of grading specifications, the writer quite agrees with the author that the stations of free haul, and also the stations of center of mass in cut and fill, should be established. Overhaul computation on this basis can always be checked at any subsequent time. Unless some such arbitrary method of calculation be adopted and set forth clearly in the specifications, the long-drawn-out controversy over the question will always remain a subject of annoyance and misunderstanding.

To strike out the overhaul clause from railroad grading specifications would be for the best interests of both parties, and would inaugurate a system of square dealing. As remarked before, the only fair way to pay for grading is to pay for the excavation and also for the embankment. With uniformity of classification and the elimination of the overhaul clause, the contractor would always know what conditions he had to meet, and his bid could be arranged intelligently. Railroad contracting would then become a straightforward business proposition, instead of a hazardous risk, under which, to be absolutely safe, the contractor must place his figures high enough to cover the contingencies that may arise under the classification uncertainties. Mr. Parker.

HALBERT P. GILLETTE, M. AM. SOC. C. E. (by letter).—The author has done a service to the profession of engineering, as well as to the business of contracting, by collecting so many examples of ambiguous specifications for excavation. It would be difficult, however, to select any work so hard to define in words as the classes of excavation. Earth merges by insensible degrees into hardpan or shale; hardpan and shale merge into conglomerate and slate by equally insensible degrees; geologically, there is no dividing line between what is called "earth" and what is called "rock." This fact is well illustrated in the dictionary definitions cited by the author, and it is shown even better by the definitions found in textbooks on geology. It may be seen, therefore, that some arbitrary test should be prescribed to differentiate rock from earth when different prices are to be paid for each. The ancient "plow test" has many adherents, but in its usual form it is probably more productive of legal trouble than any other clause ever devised by an engineer. Some years ago the State Engineer of New York suffered most unjust criticism because of supposedly unfair classification of excavation by the plow test, and his retirement from office was probably due in large measure to this unjust criticism. Mr. Gillette.

The writer, while on the editorial staff of *Engineering News,* in 1903, wrote a series of editorial articles criticizing specifications, and he recalls having written one suggesting an earth classification test somewhat similar to that proposed by the author. Instead of specifying a furrow 10 by 10 in., however, he suggested a minimum number of cubic yards loosened per 10-hour day by a 6-horse plow. It still seems to the writer to be a much better plan to specify in cubic yards, for the cubic yard is the unit of cost, and, after all, the object is to secure some definite cost classification. A 10 by 10-in. furrow cut by four horses means nothing very definite unless the amount of useful work is specified, either by naming the average speed of cutting, or the average number of cubic yards to be loosened in a given time; but why limit "earth" to such easy material as can be loosened by four horses? Ten-horse plows are very

Mr. Gillette.

common in the West, where driving with a jerk-line is practiced. There is a serious objection to the plow test wherever work is to be done with steam shovels, and the objection is that it is practically impossible to apply the test in many cases. In a through cut, for example, the top 4 ft. of material may be loam, below which may lie an indurated clay of hardpan consistency. The steam shovel exposes a vertical face upon which no plow test can be made; unless this 4-ft. stratum is stripped, the plow test is of no use on the surface. The bottom of the pit may be solid rock. Of what practical use is the plow test under such conditions?

Many other conditions might be mentioned to show the exceeding difficulty of applying a plow test in a satisfactory manner. One more will suffice. In soil of glacial origin, lenses of hardpan are frequently encountered, surrounded by gravel, sand, or shot clay. It is impracticable to strip these lenses in steam-shovel work for the purpose of using a plow test, and, without stripping, no such test is possible.

The plow test, therefore, may serve in plow work, but it is practically useless in much of the work done by steam shovels.

What test, then, shall be applied? In the writer's book on earthwork,* the suggestion is made that excavation be classified by samples taken from specified locations on the profile. No practical method of specifying with any degree of exactitude seems possible to the writer, and a varied experience, embracing excavation at different places across the American continent, has served to emphasize this conclusion.

It is true that this method of "specifying by samples" involves digging test-pits and sinking bore-holes, but the writer is firmly convinced that no engineer ever spent a dollar that returned a greater dividend than the one spent in ascertaining the character of the excavation before the award of the contract.

On any extensive piece of excavation, earth should be dug, and rock should be blasted, by the engineer, to ascertain its quality, as well as to determine the relative quantities of each class. The engineer who cannot persuade his employer to go to this extra expense is hardly fit to be in charge of the work; or, if he is fit, he does himself an injustice in not resigning if his advice is ignored.

The writer agrees with the author in recommending the "end-area" formula, provided the field engineer is taught how to space his cross-sections.

The author, in common with some other writers, conveys a wrong impression by saying that the "end-area" formula is compulsory in some States. It is not compulsory in any State, but laws do provide that, "in the absence of any specified agreement as to measurement," the "average end-area" formula must be used.

* "Earthwork and Its Cost," p. 21.

Mr. Gillette.

In the matter of specifying that embankments shall be built in layers, the writer is in hearty accord with the author, and has already expressed himself at some length elsewhere. It is the acme of asininity to specify that embankments shall be built in layers when there is no intention of enforcing the specification.

As to sub-contracting, the writer also agrees with the author. In the writer's judgment, the ideal method of doing all work in the world is by some sort of contract system, and the further down the line the method can be carried, the better. A sub-contractor is a superintendent or foreman whose wages are paid in the form of profits. A man working by piece-work, or under a bonus system, is a sub-sub-contractor, and his wages, in turn, depend directly upon his energy and skill.

Engineers will always have more or less trouble with contractors; but he is a weak engineer, or a lazy one, who permits such troubles to lead him into the wasteful method of doing work by day labor when it is possible to do it by contract, by sub-contract, or by sub-sub-contract. The writer has recently examined extensive records of cost of railroad work done by contract and by company forces working on the day-labor plan. It is no unusual thing to find that company work has cost 200% more than contract work under precisely the same conditions. For example, it has cost one railway $1 600 per mile to lay and surface track, where $500 would have been sufficient under a contract. The grading cost was equally disproportionate.

If any engineer believes he can do work cheaper for a company by day labor than by contract, he will be doing the company the greatest possible service by resigning and taking the contract himself. Then the knowledge that he must make his brains make the muscles of his men work, or no pay for his time will be had, is certain to test his ability to effect economies as no other condition can.

Then, let there be an end to these absurd clauses prohibiting sub-contracting. Now that engineers, in rapidly increasing numbers, are entering the business of contracting, there is reason to hope for more contributions such as this admirable paper. Let the discussion be one of hard blows, if need be, for, as long as it brings out the honest opinions of both parties as to a contract, it is bound to result in more reasonable prices, fewer lawsuits, and greater economy for all concerned.

Mr. Kennedy.

JAMES H. KENNEDY, M. AM. SOC. C. E. (by letter).—This paper is most interesting and instructive, as the author appears to view the subject principally from the standpoint of the contractor, and presents the generally accepted views of contractors on contracts, specifications, classifications, etc., in a very able and lucid manner.

Mr. Kennedy.

This view of the subject will be of great value to many engineers who have never been called upon to look at these matters as the contractor sees them. A somewhat limited experience as a contractor's engineer, in cases where estimates failed to cover working expenses, leads the writer to agree with most of the conclusions arrived at by Mr. Dennis. It may also be added that these conclusions will be found to be of great help in understanding human nature as exhibited by the contractor who digs deeper and deeper into his pocket to meet current expenses, not knowing where he is likely to get off, or whether or not he is getting justice at the hands of the engineer.

The usual railway contract is, no doubt, a very one-sided agreement, altogether in the interests of the railway company, from the contractor's point of view, and its conditions generally clothe the engineer with autocratic powers. It is so one-sided, in fact, that its provisions seldom require the engineer to take advantage of them, and so unreasonable that the contractor often disregards the objectionable clauses of his contract entirely, and, sizing up the engineer, takes his chances of being allowed to avoid such clauses on account of his knowledge of the kind of engineer with whom he has to deal. Nevertheless occasions arise when it is necessary, in the interests of the railway company, to take advantage of one or all of these rigid clauses of the contract; consequently, it is doubtful whether they will ever be eliminated entirely. The writer cannot agree with the author, however, when he says:

"The time has about come for the companies to be willing to assume the risk of their own acts and plans, and not to saddle these risks further upon contractors."

It is not clear that the contractor assumes any risk except his own, with the exception of an occasional change of location which is unfavorable to him; this, however, is usually provided for in the contract.

Again, in the matter of classification of material, where there is a classification varying from earth at one end of the scale to solid rock at the other, and with intermediate classes of hardpan, loose rock, etc., between, there is no trouble in classifying the earth and rock, as all specifications are somewhat clear and definite; but this is not so with the intermediate classes, especially where it is the custom to allow a percentage of each class, varying with the hardness of the material or the cost of handling. It may be safely stated that, not only will different engineers seldom give exactly the same classification, but the same engineer is likely to vary his classification somewhat on different days when passing over the work, and, if notes be kept and compared, he will be surprised at the different classifications which he has made from day to day for the same

work; consequently, there is no definite and fixed standard by which all engineers will classify in the same way; but each must follow his individual ideas. In time these ideas become fixed, so that, in the mind of the contractor, they become what may be called the engineer's personal equation. Every engineer who follows railway work has this personal equation, whether he knows it or not; consequently, contractors, when tendering for work, give more attention to obtaining information as to who is to be the engineer, than to studying up the requirements of the contract and specifications. This will always be the case, to a certain extent, whether or not all work under the same standard specifications. Mr. Kennedy.

In regard to the extra items connected with all contracts, the author, no doubt, has the correct idea, and the writer fully agrees in the opinion that:

"One matter should not carry the cost of another matter, unless the latter be uniformly a concomitant of the first and is specified so definitely that its quantity and cost can be calculated."

As an illustration of the meaning here intended, an item of clearing may be assumed to be a single large spreading tree in the middle of a cleared field, which has cost the contractor $10 to remove, and his contract price for clearing to be $20 per acre. The writer's idea is that this should be returned in the estimate, as a sufficient area, to amount to $11; this is the cost plus the usual percentage, independent of actual measurement on the ground. The reason for this opinion is: that there is no way by which the contractor can obtain a definite idea of what he might be allowed for this particular piece of work, and could not have provided for it. It may be objected, that the above case would be reducing the work to a force-account basis, and that it would be unfair to the company to pay for the odds and ends on such account, while the principal part of the work is done by measurement at contract price; but the case here assumed is only intended as an illustration of a case which, in its nature, cannot be covered by actual measurement. In a general way, there is no valid reason why such items as foundation pits, drains, etc., should not be measured up and returned at actual measurements, but it is clear that the railway engineer cannot avoid entirely the use of the force account.

On the whole, the idea of a standard form of contract, which could be used by all companies, is a good one; and if the Society should take up the matter, there is no reason why the Standard form of Contract and Specifications of the American Society of Civil Engineers should not become as well known as the Standard Rail Section of the American Society of Civil Engineers.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

LIBERATION OF AIR IN SIPHONS.

Discussion.*

By P. M. Pritchard, Assoc. M. Am. Soc. C. E.

Mr. Pritchard.

P. M. Pritchard, Assoc. M. Am. Soc. C. E. (by letter).—It would appear to the writer to be a somewhat difficult matter to estimate, even approximately, the quantity of air liberated from water flowing through a siphon, owing to the fact that some of the air, freed from solution in the water by the reduction of pressure, remains entrained in the water and is carried with it through the siphon. The quantity of air or gas held in solution by the water and liberated for a given reduction of pressure can be found by a simple laboratory experiment.

The writer has recently installed a siphon of considerable size, as shown by Fig. 2. In this case, a receiver was fixed near the

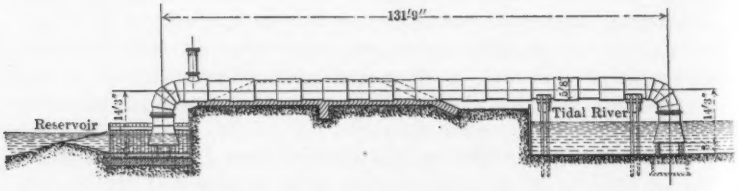


Fig. 2.

delivery end of the siphon with the object of catching air liberated from the water and swept along the top of the siphon pipe.

* This discussion (of the paper by Charles Anthony, Jr., M. Am. Soc. C. E., printed in *Proceedings* for January, 1907), is printed in *Proceedings*, in order that the views expressed may be brought before all members for further discussion.

Mr. Pritchard.

At present a small steam jet extracts the air collected in the receiver while the siphon is at work, but, from the appearance of the water delivered by the siphon, it is evident that a large quantity of the air liberated from the water is entrained and carried away with it.

It seems that it ought to be possible to design an ejector, operated by the water itself, to exhaust the air accumulated in the receiver, and experiments are being made on these lines.

Incidentally, the writer would say that the siphon shown in Fig. 2 is the largest of which he has been able to find any record. With a 6-in. difference of water level, the delivery, very approximately, is 1 500 000 English gal. per hour.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

FELICIAN SLATAPER, M. Am. Soc. C. E.*

DIED SEPTEMBER 11TH, 1906.

Felician Slataper was born in Trieste, Austria, on April 19th, 1828. After his early schooling, he entered the Austrian Naval Academy at Venice in 1841. Leaving this academy in 1844, he pursued his studies until 1848 in the Polytechnic College at Vienna. In 1850, he determined to seek his fortune in a new land, and sailed from Trieste to San Francisco, and from there to the Isthmus of Panama, where he was employed on the rebuilding of the roads across the Isthmus. Here he was stricken with fever, and, while convalescing, set sail for New York, arriving early in 1851.

Owing to his limited knowledge of English, Mr. Slataper found some difficulty in procuring permanent employment in New York; and, in the spring of 1852, he made his way to Pittsburg, and secured employment with the Pennsylvania Railroad as Assistant Architectural Draftsman, under Oliver W. Barnes, M. Am. Soc. C. E., who was at that time the Principal Assistant Engineer in charge of the construction of the Western Division of the Pennsylvania Railroad, and of the Machine Shops and Round House in Pittsburg. Mr. Slataper was engaged chiefly upon the tracings of the plans of these buildings. He remained in this employment a year or more, and then went to the Pittsburg and Connellsville Railroad, serving under Mr. Barnes, who had left the service of the Pennsylvania Railroad Company in the spring of 1853.

Later, Mr. Slataper moved to Washington, D. C., and took a position in the Government service. In 1861, he went to the Downingtown and Waynesburg Branch of the Pennsylvania Railroad, then being constructed by Mr. Barnes as Chief Engineer, and made a topographical survey and map of the line and the adjoining country.

In 1863 Mr. Slataper took service with the Pittsburg, Fort Wayne and Chicago Railway Company, as Division Engineer, continuing in that service until 1869 when that road was leased by the Pennsylvania Railroad Company. He continued with this company, and, in 1870, entered the service of the Pennsylvania Company, organized to operate the Pittsburg, Fort Wayne and

* Memoir prepared by Thomas Rodd, M. Am. Soc. C. E.

Chicago Railway and other lines west of Pittsburg owned or controlled by the Pennsylvania Railroad Company, remaining with that company for 25 years. In March, 1871, he was appointed Chief Engineer, and retained that position until 1889, when he was made Consulting Engineer, which position he finally gave up in May, 1895, having then been on leave of absence since September, 1892, residing in Trieste, his birthplace.

During the years 1863 to 1867 inclusive, Mr. Slataper was identified especially with the design and construction of the Allegheny River Bridge of the Pittsburg, Fort Wayne and Chicago Railway, making nearly all the drawings and superintending its construction, while holding the title of Engineer and Architect under the eminent engineer, the late John B. Jervis, Hon. M. Am. Soc. C. E., then Chief Engineer. This remarkable structure, a double-track, through, lattice bridge with three trusses, endured, until 1903, under the heavy traffic of the railway. In 1893, the enormous 500 000-lb. gun, exhibited by the United States Government at the World's Fair in Chicago, was moved over this structure on its heavy steel special cars, the bridge having no supports but its own stone piers, and being practically in its original condition, save for some unavoidable deterioration. This bridge had a total length of 1 172 ft., composed of five spans of 164 ft. each, and four spans of deck plate-girders, each 88 ft. long. It will be recognized by engineers that this life of 35 years, during that period of heavy traffic and increasing loads, is sufficient testimony to the ability and painstaking care of the man to whom is clearly due the credit of the design and execution of this great work.

On September 23d, 1856, Mr. Slataper was made a citizen of the United States in the United States District Court at Pittsburg, Pennsylvania.

In 1870 the City Councils of Pittsburg elected three Water Commissioners, serving without compensation. They employed hydraulic engineers and made a report, after a thorough investigation, on the problem of water supply for the city. Mr. Slataper was the first man selected, and the only one who had a unanimous vote. Messrs. J. K. Moorhead and George A. Berry were the other members of this commission. Mr. Slataper was very active and efficient in the work of the commission and in the selection of the hydraulic engineers, who were the late E. S. Chesbrough, M. Am. Soc. C. E., and the late Moses Lane, M. Am. Soc. C. E. The report of the commission was duly made, and with modifications and extensions, was carried out, and the city water supply of Pittsburg as it is to-day is the result of that commission. Besides this work, Mr. Slataper was frequently employed in an advisory capacity, as well as in designing works for other railroads.

In 1876 Mr. Slataper was one of the judges in deciding the awards of prizes on railway exhibits at the Centennial Exhibition in Philadelphia.

During the eighteen years of his incumbency as Chief Engineer of the Pennsylvania Company, several new railroads were located and constructed by him, and, owing to difficulties of construction and controversies with other lines seeking to occupy the same ground, some of them were built under very adverse conditions. In all the work of reconstructing the Fort Wayne Railroad, he displayed great resourcefulness and ability, and he always required from others the same diligent and persistent effort which he himself gave to all the work in his charge. While his instincts were naturally kind and his manner courteous, he held every one to a strict accountability, and was content with nothing but the best service from all his subordinates. His unswerving loyalty to duty, and his high ideal of integrity earned for him the affection and respect of his associates, while his pleasant manner and his willingness to adapt himself to his company and surroundings made him a welcome companion in all the circles of his business and social life.

On August 19th, 1853, Mr. Slataper married Eliza Jane Lee, the daughter of Dr. Daniel Lee. The surviving children of this marriage are Daniel Lee Slataper, of Alvin, Texas, and Mrs. S. W. Kerr, of Philadelphia. Mrs. Slataper died in October, 1892. In November, 1893, he married again. His widow and her daughter, Ada, 10 years old, survive him, residing in their beautiful home in Trieste.

During his long and active career, his naturally great care and thought for all his affairs led him to exercise his good judgment in both saving money and investing it carefully, so that at the time of his death he was fairly well provided with this world's goods, of which he made a just and carefully-thought-out division between his surviving heirs on both sides of the Atlantic.

Mr. Slataper was elected a Member of the American Society of Civil Engineers on September 15th, 1869, and while he sometimes attended the Conventions of the Society, his very busy life, as well as his inclinations to follow his duties very closely, left him little or no opportunity to make any contributions to the literature of the Society, nor did his tastes or his inclinations lead him in this direction. He was, however, always faithful, competent, and diligent, gaining the respect and esteem of his friends and associates, rendering devoted service to his employers, and leading such an exemplary life as to be, in all respects, in his family, social, and business life, a worthy example to those who had the privilege of working under or being associated with him.

The writer visited Mr. Slataper in March, 1906, at Trieste, and found him apparently in very good health, tall, with a full head of hair and full beard, both perfectly white. He was slightly bowed at the shoulders, but was active in body and mind, and seemed in a better situation to enjoy the true felicities of life than ever before. But this was his last good time, and thenceforward he declined in health and strength until the time of his death, on September 11th, 1906, in his seventy-ninth year. During all this time he had the affectionate care and devotion of his family, being surrounded by every possible comfort and solaced in his last days by the memories of a well-spent life. His many friends in America will appreciate these particulars.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

(INSTITUTED 1852.)

VOL. XXXIII. No. 4.

APRIL, 1907

Edited by the Secretary, under the direction of the Committee on Publications.

Reprints from this publication, which is copyrighted, may be made on condition that the full title of Paper, name of Author, page reference, and date of presentation to the Society, are given.

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NEW YORK 1907.

Entered according to Act of Congress, by the AMERICAN SOCIETY OF CIVIL ENGINEERS, in the office of the Librarian of Congress, at Washington.

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ON STATUS OF METRIC SYSTEM:—Stacy B. Opdyke, Jr., John Waterhouse, D. A. Molitor.

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER.....5913 Columbus.
CABLE ADDRESS....."Ceas. New York."

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

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MINUTES OF MEETINGS.

OF THE SOCIETY.

March 20th, 1907.—The meeting was called to order at 8.45 P. M.; Mansfield Merriman, M. Am. Soc. C. E., in the chair; T. J. McMinn, Assistant Secretary, acting as Secretary; and present, also, 152 members and 24 guests.

A paper by C. E. Grunsky, M. Am. Soc. C. E., entitled "The Lower Colorado River and the Salton Basin," was presented in abstract by the Assistant Secretary, who also read a communication from the author in reference to the closure of the breach in the banks of the Colorado River. Written discussions by Messrs. T. G. Dabney, W. G. Price and Rutger B. Green, were also presented, and the paper was discussed orally by W. deH. Washington, Assoc. M. Am. Soc. C. E.

The Assistant Secretary announced the following deaths:

JOSEPHUS CONN GUILD, elected Member June 1st, 1898; died February 25th, 1907.

JOHN DONALD MACLENNAN, elected Member October 4th, 1899; died February 26th, 1907.

A communication from the Secretary, who is now in Mexico, giving general preliminary information as to progress of the arrangements for the Annual Convention, which is to be held in that city, was read for the information of those present.

Adjourned.

April 3d, 1907.—The meeting was called to order at 8.45 P. M.; A. L. Bowman, M. Am. Soc. C. E., in the chair; Charles Warren Hunt, Secretary; and present, also, 142 members and 27 guests.

The minutes of the meetings of February 20th and March 6th, 1907, were approved as printed in *Proceedings* for March, 1907.

A paper by C. C. Schneider, entitled "Movable Bridges," was presented in abstract by the author.

The Secretary read communications on the subject from Messrs. C. R. Dart, J. R. Worcester, A. H. Smith, H. D. Hess and Ralph Modjeski, and the paper was discussed orally by Henry B. Seaman, M. Am. Soc. C. E., and the author.

Ballots for membership were canvassed, and the following candidates elected:

AS MEMBERS.

WALTER JULES DOUGLAS, Washington, D. C.
EDWARD GAGEL, West Haven, Conn.
ROBERT EUGENE GAUT, Chicago, Ill.
JULIUS GEORGE HOCKE, New York City.
ARCHIBALD ROGERS LIVINGSTON, Cañon City, Colo.
RALPH DAVENPORT MERSHON, New York City.
FRED FORREST MOORE, New York City.
GEORGE FREDERICK MORSE, New York City.
MERRITT HAVILAND SMITH, White Plains, N. Y.
HENRY MORTON STONE, Cedar Rapids, Iowa.

AS ASSOCIATE MEMBERS.

THOMAS CLARK ATWOOD, New York City.
GUSTAVE STORM BERGENDAHL, St. Louis, Mo.
WILLIAM HENRY CHASE, New York City.
GEORGE ROBERT DAVIS, Sacramento, Cal.
CHARLES ALTON ELLIS, Ambridge, Pa.

Carl Brandes Ely, Harrisburg, Pa.
Leslie Monroe Fry, Crookston, Minn.
John Howell Griffith, Allegheny, Pa.
Borden Baker Harris, Manila, Philippine Islands.
Henry John Hewat, Paterson, N. J.
James Wallace Higgins, New York City.
John Brewster Hodgdon, Galena, Kans.
Joseph Nelson Hood, Long Island City, N. Y.
Henry Roberts Hortenstine, New Orleans, La.
William Augustus Howell, Newark, N. J.
John Louis Lee, East Providence, R. I.
James Albert McDonough, Wheeling, W. Va.
Henry Peyton Mobberly, Bunkie, La.
Alfred Lee Moorshead, Jersey City, N. J.
William Jacob Mozart, Malden, Mass.
Hilmar Torleiv Opsahl, Detroit, Mich.
James Foster Rodenbough, New York City.
Francis Joseph Seery, Ithaca, N. Y.
Alexander Jenifer Taylor, Wilmington, Del.
Howard Warren Underwood, Aspinwall, Pa.
Thomas James Wasser, Jersey City, N. J.
Willard Olney White, Rome, N. Y.

As Associates.

John Hervid Lundberg, New York City.
Demarest Haring Mapes, Mt. Vernon, N. Y.
Albert Smith, Lafayette, Ind.
Joseph Mason Van Name, Brooklyn, N. Y.

The Secretary announced:

The transfer of the following candidates by the Board of Direction, on April 2d, 1907:

From Associate Member to Member.

Frank Henry Constant, Minneapolis, Minn.
John Fillmore Hayford, Washington, D. C.
Charles Holland Moritz, Niagara Falls, N. Y.

The election of the following candidates by the Board of Direction:

As Juniors.

On January 3d, 1907:

Thomas Hagen Gronwall, Ambridge, Pa.

On March 5th, 1907:

CHARLES E. APPLE, Meridian, Miss.
ELIJAH HERBERT DUNMIRE, Lawrence, Kans.
ASAHEL CLARK TOLL, San Francisco, Cal.

On April 2d, 1907:

ALFRED EUGENE BARLOW, JR., Brooklyn, N. Y.
THOMAS LILLY FOUNTAIN, New York City.
GEORGE MERRICK HERRON, Vallecito, Cal.
ARTHUR RAYMOND HOLBROOK, New York City.
WILLIAM WASHINGTON MITCHELL, Hawley, Minn.
OREN MCKENNEY MOULTON, Waterbury, Conn.
FRANK AUSTIN NIKIRK, San José, Cal.
CHARLES FRANKLIN PECK, Lincoln, Nebr.
JOHN MARIE THOMAS RICE, Pittsburg, Pa.
CHARLES SIESEL RINDSFOOS, Shawinigan Falls, Que., Canada.
WARD REID ROBINSON, Urbana, Ill.
EDWARD GEORGE WALKER, New Bushey, England.
HUGH LEMUEL WILEY, Fort William, Ont., Canada.
RUSSELL SHERWOOD WISE, Passaic, N. J.

The Secretary announced the following death:

JAMES HERVEY ARMINGTON, elected Member July 6th, 1870; died October 14th, 1906.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

January 3d, 1907.—President Stearns in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bowman, Ellis, Gibbs, Gowen, Kuichling, Noble, Schneider, Sherrerd, Smith, and Webster.

A draft of the Annual Report of the Board of Direction was presented by a committee appointed for the purpose, and was adopted as the report of the Board to the Society.

John S. Sewell, M. Am. Soc. C. E., was appointed to represent the Society at the Fiftieth Anniversary of the American Institute of Architects to be held in Washington, D. C., January 8th, 1907.

The report of the committee appointed to recommend the award of prizes for the year ending with *Transactions* for July, 1906, was presented, and the following awards were made:

The Norman Medal to John Stephen Sewell, M. Am. Soc. C. E., for his paper entitled "The Economical Design of Reinforced Concrete Floor Systems for Fire-Resisting Structures."

The Thomas Fitch Rowland Prize to George B. Francis, M. Am. Soc. C. E., and William F. Dennis, M. Am. Soc. C. E., for their joint paper entitled "The Scranton Tunnel of the Lackawanna and Wyoming Valley Railroad."

It was resolved that the Collingwood Prize for Juniors be not awarded for this year.

The Secretary reported that the tablet commemorative of the International Engineering Congress of 1904, which had been authorized by the Board, had been completed and erected in the Library of Washington University at a total cost of $230.

Chas. Warren Hunt was appointed a member of the John Fritz Medal Board of Award for the next four years.

The following resignations were accepted:

MEMBERS: Edward W. Eckert, William F. Keene, William W. Kenly. ASSOCIATE MEMBERS: William L. Abbott, James A. Woodruff. JUNIORS: Mark L. Ireland.

Action was taken in regard to members in arrears for dues.

Applications were considered, and other routine business transacted.

Seven Associate Members were transferred to the grade of Member, and fourteen candidates for Junior were elected.

Adjourned.

January 16th, 1907.—3 P. M.—The Board met, as required by the Constitution, at the Society House, during the Annual Meeting; President Benzenberg in the chair; Chas. Warren Hunt, Secretary;

and present, also, Messrs. Bates, Bissell, Bowman, Christie, Fisher, Gibbs, Hodgdon, Horton, Knap, Schneider, Sherrerd, Smith, Stearns, Swensson, and Tillson.

The following standing committees of the Board were appointed:

Finance Committee: J. A. Bensel, George Gibbs, Allen Hazen, J. A. Ockerson, George S. Pierson.

Publication Committee: M. R. Sherrerd, Onward Bates, B. R. Green, J. Waldo Smith, Emil Swensson.

Library Committee: George W. Tillson, H. Bissell, James Christie, F. W. Hodgdon, Chas. Warren Hunt.

The President announced that the next business of the Board was the election of a Secretary. Mr. Hunt retired. A ballot was taken, and Mr. Hunt received the unanimous vote of those present. The President announced Mr. Hunt's election as Secretary of the Society.

Adjourned.

February 5th, 1907.—8.30 P. M.—Past-President Schneider in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bissell, Bowman, Hodgdon, Sherrerd, Smith, and Tillson.

A report was received from the Committee appointed to make a recommendation as to the time and place for holding the next Annual Convention. It was unanimously decided that the next Annual Convention be held in the City of Mexico.

Messrs. A. L. Bowman, J. Waldo Smith and Chas. Warren Hunt were appointed a committee to take charge of Convention matters in behalf of the Board of Direction.

The time for holding the Convention was left to the discretion of the Committee of the Board, provided such time shall be between June 20th and July 20th, 1907.

Applications were considered, and other routine business transacted.

Four Associate Members were transferred to the grade of Member, and eighteen candidates for Junior were elected.

Adjourned.

March 5th, 1907.—9.10 P. M.—President Benzenberg in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bissell, Bowman, Hodgdon, Horton, Knap, Noble, Ockerson, Sherrerd, Smith, Stearns, Storey, Swensson, and Tillson.

The same geographical districts as were established April 3d, 1906, were retained as the divisions occupied by the membership of the Society for the current year.

Applications were considered, and other routine business transacted.

Twelve Associate Members were transferred to the grade of Member, and ten candidates for Junior were elected.

Adjourned.

April 2d, 1907.—8.30 P. M.—Past-President Schneider in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bissell, Bowman, Christie, Gibbs, Hazen, Hodgdon, Knap, Landreth, Smith, and Tillson.

Matters concerning the Annual Convention were considered, and the time for holding the Convention was fixed for the week beginning July 8th, 1907.

Invitation was received requesting that an authorized representative of this Society be appointed to be present at the dedication of the building given by Andrew Carnegie for the joint occupation of Engineering Societies, April 16th and 17th, 1907, and Nelson P. Lewis, M. Am. Soc. C. E., was appointed as such representative.

Applications were considered, and other routine business transacted.

Three Associate Members were transferred to the grade of Member, and fourteen candidates for Junior were elected.

Adjourned.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, May 1st, 1907.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and the Reports of the Committees on the Effects of the San Francisco Earthquake of April 18th, 1906, on Engineering Constructions, will be presented for discussion.

These reports were printed in *Proceedings* for March, 1907.

Wednesday, May 15th, 1907.—8.30 P. M.—At this meeting a paper entitled "The Reinforced Concrete Bridge Across the Hudson River at Sandy Hill, New York," by William H. Burr, M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings*.

ANNUAL CONVENTION.

The Thirty-ninth Annual Convention of the Society will be held in the City of Mexico during the week beginning Monday, July 8th, 1907.

If favorable replies are received from a sufficient number of members, it is probable that arrangements can be made for a special train to the City of Mexico. It is hoped that such a train may be started from St. Louis, but, if this is not possible, one will be made up at San Antonio, Texas.

A circular, with return blanks, is now in press, and gives general information about the Convention, as far as arranged, and, as soon as replies are received from the membership, other circulars will be sent out.

The following Committees have been appointed to take charge of the arrangements:

COMMITTEE OF THE BOARD OF DIRECTION.

A. L. Bowman,
J. Waldo Smith,
Chas. Warren Hunt.

LOCAL COMMITTEE.

William G. Moler,
John B. Body,
T. A. Corry,
E. H. Drury,
S. J. Fortin,
Roberto Gayol,
Lewis Kingman.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all meetings:

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Society of Engineers, 17 Victoria Street, Westminster, S. W., England.

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Civil Engineers' Club of Cleveland, 718 Caxton Building, Cleveland, Ohio.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa.

Engineers' Society of Western Pennsylvania, 803 Fulton Building, Pittsburg, Pa.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

Louisiana Engineering Society, 604 Tulane-Newcomb Building, New Orleans, La.

Engineers' Club of Central Pennsylvania, Corner Second and Walnut Streets, Harrisburg, Pa.

Engineers' and Architects' Club of Louisville, Ky., 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

Teknisk Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Société des Ingénieurs Civils de France, 19 Rue Blanche, Paris, France.

Svenska Teknologförenigen, Brunkebergstorg 18, Stockholm, Sweden.

Institute of Marine Engineers, 58 Romford Road, Stratford, London, E., England.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Pacific Northwest Society of Engineers, 617–618 Pioneer Building, Seattle, Wash.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Memphis Engineering Society, Memphis, Tenn.

Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

The Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Institution of Engineers of the River Plate, Buenos Aires, Argentine Republic.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Cleveland Institute of Engineers, Middlesbrough, England.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Rochester Engineering Society, Rochester, N. Y.

Brooklyn Engineers' Club, 197 Montague Street, Brooklyn, N. Y.

Montana Society of Engineers, Butte, Montana.

SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

In reference to this work, the Appendix* to the Annual Report of the Board of Direction for the year ending December 31st, 1906, contains a summary of all searches made to that date.

* *Proceedings*, Vol. XXXIII, p. 20 (January, 1907).

ACCESSIONS TO THE LIBRARY.

From March 12th to April 9th, 1907.

DONATIONS.*

PROBLEMS OF THE PANAMA CANAL.

Including Climatology of the Isthmus, Physics and Hydraulics of the River Chagres, Cut at the Continental Divide, and Discussion of Plans for the Waterway, with History from 1890 to Date. By Henry L. Abbot. Cloth, 9 x 6 in., illus., 12 + 269 pp. New York, The Macmillan Company, 1907. $2.00 net.

The official documents and records of the New Panama Canal Company, prepared by the Commission appointed to report on the topography, hydrography and geology of the Isthmus of Panama, while very complete, are in the French language, and, therefore, are not widely known in the United States. The author, as Consulting Engineer for the Company, spent seven years studying the technical features of the problem, having had free access to the original notes. This book, therefore, should contain valuable information of wide interest to the American people. The first edition, issued in 1905, includes a brief history of the project from the time of the organization of the New Panama Canal Company, in 1894, to the transfer of the work to the United States Government in 1904; together with extensive studies of the physical and engineering features of the problem. This, the second edition, as stated in the preface, brings the history and technology of the work up to the beginning of 1907. It includes a history of the work since the Canal was purchased by the United States; explains and discusses the new studies and resulting plans made by the Board of Consulting Engineers, and the final action of the Government thereon; introduces new and valuable climatological and hydraulic data; and describes the methods adopted for the construction of the Canal by contract. The Contents are: The New Panama Canal Company; The Canal Under the Control of the United States; The Rival Routes; Physical Conditions on the Isthmus; The Chagres River; Disposal of Rainfall, Basin above Bohio; Engineer Projects for the Canal; Appendix: Panama and Nicaragua in 1898. There is an index of eight pages and a copy of the map of the Panama Canal, which was made for the French Company.

THE WALSCHAERT LOCOMOTIVE VALVE GEAR.

A Practical Treatise on the Locomotive Valve. By W. W. Wood. Cloth, 8 x 5 in., illus., 193 pp. New York, The Norman W. Henley Publishing Co., 1907. $1.50.

The author states that this book is intended for the engineer or mechanic who wishes to extend his knowledge of locomotive valve gears. It contains a history of the development of the Walschaert valve gear by American and European designers, and of its evolution into the mechanically correct locomotive valve gear of the present day. The book is divided into four parts. I, "Analysis of the Walschaert Valve Gear," in which chapter the theory and action of the valve gear is explained in the simplest possible manner, the various parts being taken up and studied individually. II. "Designing and Erecting the Walschaert Valve Gear"; in this chapter, the design and erection of this valve gear is explained for the scientific engineer and master mechanic. Diagrams and formulas are given for designing and laying out the valve gear for any locomotive, with hints on the inspection of the gear and rules for setting the valves. Separate cardboard models of the outside admission D-slide valve and the piston valve of inside admission to be used in connection with these diagrams, are contained in a pocket in the book. III, "Advantages of the Walschaert Valve Gear"; this part of the book has to do with the actual work of the valve gear on the road, with its advantages, and arguments are given for its use as against the Stephenson link motion. IV, "Questions and Answers Relating to the Walschaert Valve Gear"; this chapter consists of questions and answers which are not only descriptive of the valve gear, etc., but also refer to breakdowns which may happen to a locomotive equipped with the Walschaert valve motion. There is an index of eight pages.

* Unless otherwise specified, books in this list have been donated by the publisher.

SWITCHBOARDS

For Power, Light and Railway Service—Direct and Alternating Current—High and Low Tension. By Wm. Baxter, Jr. Cloth, 8 x 6 in., illus., 192 pp. New York, The Derry-Collard Company, 1906. $1.50.

All sizes and kinds of switchboards, except those connected with telephone service, are dealt with in this book. The first part is devoted to descriptions of how switchboards are connected for single and multiple-generator plants and also for the three-wire system. In the second part, the author takes up the subject of switchboards as used in actual practice, describes the different forms of switchboards for direct and alternating currents and high and low tension for power, light and railway purposes, and also the construction of switchboards. Switches, circuit breakers and lightning arresters are described in the last part of the book. The Contents are: Switchboards; Operating Generators in Parallel; Arrangement of Instruments and Switches; Diagrams of Boards in Actual Service; Construction of Switchboards; Switchboards for Arc-Lighting Circuits; Switchboards for Alternating Currents; Switchboards for Series Alternating Current Arc Lighting; High-Tension Switchboards; Switches; Circuit Breakers; Lightning Arresters. There is an index of three pages.

GRAPHICAL HANDBOOK FOR REINFORCED CONCRETE DESIGN.

By John Hawkesworth, Jun. Am. Soc. C. E. Cloth, 11 x 9 in., illus., 6 + 64 pp. New York, D. Van Nostrand Company, 1906. $2.50 net.

This book consists of a series of plates showing the design of beams, slabs and columns by means of plotted curves, together with practical examples explaining the method of using each plate. It is stated that the design of most of the simpler forms of reinforced concrete construction may be ascertained directly from these plates without the performance of any of the computation ordinarily required. The unit stresses prescribed by the Building Code of New York City have been adopted throughout as a standard. The author states that the book is intended chiefly for architects and engineers who may be required only occasionally to design work in reinforced concrete and for whom the use of a graphical handbook should render it unnecessary to call in expert assistance. The Contents are: Plate I.—Values of Constant (K), for Determining Resisting Moments; Plates II. and III.—Design of Slabs under Various Conditions of Span and Loading; Plate IV.—Spacing of Square Bars Required to Obtain a Given Area of Metal Cross-Section per Foot of Width; Plate V.—External Bending Moment in Footing Slabs, Due to Superimposed Column Loads; Plates VI. and VII.—Resisting Moment per Inch of Width for Various Depths of Beams or Slabs; Plates VIII. and VIIIa.—Conversion of Areas of Metal Cross-Section, Expressed in Sq. In. per Ft. Width, into Total Areas for any Given Width, and Showing the Number of Square Bars Required; Plate IX.—Location of the Neutral Axis; Plate X.—Shearing Resistance of Various Combinations of Concrete and Steel; Plate XI.—Square Columns Designed in Accordance with the New York Building Code; Plates XII. and XIIa.—Rectangular Columns with Various Unit Stresses, and Round Rods Required for a Given Area of Metal Cross-Section; Plate XIII.—Hooped Columns with Six Longitudinals; Plate XIV.—Hooped Columns with Eight Longitudinals; Complete Design of a Reinforced Concrete Structure; Plate XV.—Illustrates the Complete Design of a Reinforced Concrete Structure; Appendix.

COMBUSTION AND SMOKELESS FURNACES.

By Jos. W. Hays. Cloth, 9 x 6 in., illus., 7 + 104 pp. New York, Hill Publishing Company, 1906. $1.50.

This work is a treatise on the subject of the combustion of soft coal, and furnaces for burning it without smoke. It is stated in the preface that the book is designed to meet the needs of owners and engineers of steam power plants. The author begins the book with an investigation of the nature and properties of heat, which is followed by chapters on Combustion and the Boiler Furnace and Combustion and the Steam Boiler. In these chapters the question of how best to obtain combustion in steam boiler furnaces in a scientific and practical manner, is briefly, but thoroughly, discussed. The latter part of the book is devoted to the various types of the Smokeless Furnace on the market, and the author frankly criticises them with a view to helping those interested to differentiate between practical and unpractical boiler furnace devices. Technical terms and formulas are avoided in the text as much as possible. The Contents are: Heat and Combustion; Combustion and the Boiler Furnace; Com-

bustion and the Steam Boiler; The Chimney Evil; Smokeless Furnaces in General; Mechanical Stokers; Hand-Fired Furnaces; Some Conclusions. There is an index of two pages.

MANUAL OF EXAMINATIONS FOR ENGINEERING POSITIONS

In the City of New York: Questions and Answers in 3 Volumes and 8 Parts. Vol. I, Axeman, Chainman and Rodman, Leveler, Transitman and Computer. Vol. II, Assistant Engineer. Vol. III, Draftsman and Inspector. To Which are Added Appendixes Giving Examination Papers, etc., in the Civil Service of the Federal Government (Including Panama Canal and United States Navy), New York State, Boston, New Orleans, etc. By Myron H. Lewis and Milton Kempner. Cloth, 9 x 6 in., illus., various paging. New York, The Engineering News Publishing Co., 1906. $5.00.

The authors have endeavored, in this book, to supply an apparent lack of definite information as to the scope, character, frequency, etc., of civil service examinations for engineering positions, and hope that it will prove of use as a review and guide to engineers who desire to enter government employ, to Civil Service Examiners in preparing new papers, and to instructors and students in engineering schools for the purpose of review. The work includes more than two thousand questions, and answers to about a thousand questions. The information included in the book is divided into two parts: "Previous Examination Papers" and "Typical Questions and Answers." Regarding the "Previous Examination Papers," it is stated that while the questions may not be worded exactly as given at the examinations, they embody the substance of those asked. The "Typical Questions and Answers" are not intended by the authors to be perfect or complete, as opinions differ as to the best answer in many cases. The division of the subject-matter into eight parts is based on the classification obtaining in New York City. There are appendices to the first and second volumes, which contain the formulas given in the text, and also the more common formulas in use. Extracts from the rules and regulations governing the service in New York City and other pertinent data are given in the Introduction. Another new feature is the Appendix which contains rules and examinations for different Federal positions and for civil service positions in several cities in the United States.

A TEXT-BOOK ON ROOFS AND BRIDGES.

Part IV, Higher Structures. By Mansfield Merriman, M. Am. Soc. C. E., and Henry S. Jacoby, Assoc. Am. Soc. C. E. Third Edition, Revised and Enlarged. Cloth, 9 x 6 in., illus., 12 + 374 pp. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1907. $2.50.

The first three parts of this text-book include framed structures having two supports, the reactions of which are vertical. This part is devoted to those structures which have more than two supports, as continuous, draw and cantilever bridges, or to those which have two supports, the reactions of which are not vertical, as the suspension and arched systems. The investigations given are mainly those of the theory of stresses and their determination by analytic or graphic methods. Much that is new appears in this edition, which has been thoroughly revised. Lists of American bridges and arches of each type are included, with half-tone illustrations of the most notable structures, and many descriptive notes and references to engineering literature. The Contents are: Continuous Bridges; Draw Bridges; Cantilever Bridges; Suspension Bridges; Three-Hinged Arches; Two-Hinged Arches; Arches Without Hinges; References to Engineering Literature. There is an index of four pages.

Gifts have also been received from the following:

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U. S. Naval War Records Office and Library. 1 vol.
U. S. Office of Exper. Stations. 1 pam.
Univ. of Pennsylvania. 1 vol.
Webster, A. L., 29 photographs.

BY PURCHASE.

The New International Encyclopædia. 21 Vols. New York, Dodd, Mead and Company, 1907.

Technische Hülfsmittel zur Beförderung und Lagerung von Sammelkörpern (Massengütern). Von M. Buhle. III. Teil. Berlin, Julius Springer, 1906.

Producer Gas. By J. Emerson Dowson and A. T. Larter. London, Longmans, Green, and Co., 1906.

SUMMARY OF ACCESSIONS.

From March 12th to April 9th, 1907.

Donations (including 57 duplicates)	269
By purchase (including 15 volumes to complete files of annual reports and periodicals)	38
Total	307

MEMBERSHIP.

ADDITIONS.

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	Assoc. M.	Mar. 1, 1899
	M.	Mar. 5, 1907
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	M.	Mar. 5, 1907
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JUNIORS.

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JUNIORS (*Continued*).

LANT, FRANK PARSONS. Gen. Mgr., Lawyers Eng. & Surv. Co., 14th Floor, 135 Broadway, New York City.

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WORTHAM, JOHN ROOT. Asst. Engr., U. P. R. R. Co., Annex Bldg., Cheyenne, Wyo.

REINSTATEMENTS.

MEMBER.	Date of Reinstatement.
KEENE, WILLIAM FAITOUTE. Central Falls, R. I.	April 2, 1907

RESIGNATIONS.

JUNIOR.	Date of Resignation.
FOX, HENRY HEYWOOD	April 2, 1907

DEATHS.

ARMINGTON, JAMES HERVEY. Elected Member, July 6th, 1870; died October 14th, 1906.

BLACKWELL, CHARLES. Elected Member, September 7th, 1881; died December 29th, 1906.

GUILD, JOSEPHUS CONN. Elected Member, June 1st, 1898; died February 25th, 1907.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(March 11th to April 5th, 1907.)

NOTE.—*This list is published for the purpose of placing before the members of the Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles, references are given by the number prefixed to each journal in this list.

(1) *Journal*, Assoc. Eng. Soc., 31 Milk St., Boston, Mass., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générales des Chemins de Fer et des Tramways*, Paris, France.
(40) *Railway Age*. Chicago. Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.

(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 803 Fulton Bldg., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne, England.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Industrial World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(70) *Engineering Review*, New York City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.
(72) *Electric Railway Review*, Chicago, Ill., 10c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, Ill., 10c.
(77) *Journal*, Inst. Elec. Engrs., London, England.
(78) *Beton und Eisen*, Vienna, Austria.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie-Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Dinglers Polytechnisches Journal*, Berlin, Germany.
(83) *Progressive Age*, New York City, 15c.
(84) *Le Ciment*, Paris, France.
(85) *Proceedings*, Am. Ry. Eng. and M. of W. Assoc., Chicago, Ill.
(86) *Engineering World*, Chicago, Ill.
(87) *Railway Maintenance and Structures*, New York City, 10c.

LIST OF ARTICLES.

Bridge.

Design of Swing Bridges, from a Maintenance Standpoint.* C. H. Cartlidge. (4) Feb.

Design of an Indian Railway Overbridge.* (21) Mar.

Improvements on the Pennsylvania Between Philadelphia and Baltimore.* (40) Mar. 8; (14) Mar. 9.

The Reconstruction of the Parkersburg Bridge on the Baltimore & Ohio R. R.* (14) Mar. 9.

A Long Plate-Girder Bridge and Grade and Alinement Changes on the Lehigh Valley R. R. at Towanda, Pa.* Philip H. DeWitt, M. Am. Soc. C. E. (13) Mar. 14.

Missouri River Bridge of the Chicago, Milwaukee & St. Paul at Mobridge, S. D.* (40) Mar. 22.

Reinforced Concrete Bridge over the Cumberland River.* Ward Baldwin. (15) Mar. 22.

The Highway Bridge near Goshen, Ohio.* Edw. Stingel. (14) Mar. 30.

A Center-Bearing Drawbridge with Pneumatic Raising Jack and Turning Engine.* (13) Apr. 4.

Maximum Live-Load Bending Moments and Shears for Bridges Carrying Electric Cars. Frank P. McKibben, M. Am. Soc. C. E. (13) Apr. 4.

Le Pont de la Concorde sur le Seine, à Paris (1786-1791). (43) Pt. 4, 1906.

La Construction des Viaducs en Béton Armé à Deurne-Mevxem.* Paul De Heem and Ch. de Maesschalck. (30) Feb.

Bestimmung der Spannungen infolge des Einflusses von Wärmeschwankungen auf Gewölbe nach dem Verfahren mit Konstanten Bogengrössen. Robert Schönhöfer. (78) Mar.

Die Kragträgerbrücke über den St. Lorenz-Strom bei Quebec im Kanada.* G. Barkhausen. (48) Serial beginning Mar. 9.

Electrical.

Some Phenomena of Commutation.* F. G. Baily and W. S. H. Cleghorne. (77) Feb.

The Analysis of the Magnetic Leakages in Induction Motors.* Arthur Baker and John T. Irwin. (77) Feb.

Inaugural Address. (Electrical Standardisation).* R. T. Glazebrook. (77) Feb.

Testing of Electrical Machinery and of Materials for its Construction.* J. Epstein. (77) Feb.

Electrical and Chemical Energy. Gustaf M. Westman. (3) Mar.

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* Illustrated.

Electrical—(Continued).

A Method of Calculating the E. M. F. of Polyphase and Single-Phase Windings.* H. Görges. (Abstract from *Elektrotechnische Zeitschrift.*) (73) Mar. 1.
Experiments on the Distribution of Current in Accumulators.* U. Schoop. (Abstract of paper read before the French Physical Soc.) (73) Mar. 1.
The Iron Losses in Asynchronous Machines.* Thos. F. Wall. (73) Serial beginning Mar. 1.
Researches on the Heating of Armatures and Field Coils.* Ludwig Ott. (Abstract from *Mitteilungen über Forschungsarbeiten auf dem Gebiete des Ingenieurwesens.*) (73) Mar. 8.
Wireless Telegraphy between Newhaven and Dieppe.* (11) Mar. 8.
Investigation of High-Frequency, High-Potential Oscillating Discharges by Means of the Braun Tube.* E. L. Weber. (27) Mar. 9.
Calculation of Auxiliary Pole Windings.* Arthur Keller. (27) Mar. 9.
Generating Station and Sub-Station of the United Electric Company, Lemoyne, Pa.* (27) Mar. 9.
New Electric Light Plant of the Spokane & Empire Railroad Company.* (27) Mar. 9.
Niagara Power at the Lackawanna Steel Plant.* John C. Parker. (From the *Electrical Journal.*) (62) Mar. 9.
Flame Arc Lamps.* H. S. Hatfield. (73) Mar. 15.
The B. T.-H. Petrol Electric System for Commercial Vehicles.* (73) Mar. 15.
The New Central Station of the Haverhill Electric Company.* (27) Mar. 16.
The Storage Battery in Telephony.* C. E. Paxson. (27) Mar. 16.
The Baudot Telegraph System in India.* C. T. Williams. (73) Mar. 22.
The Capacity and Resistance of Aluminium Anode Films.* C. McCheyne Gordon. (Abstract from *Physical Review.*) (73) Mar. 22.
Shops of the New York Edison Company.* (27) Mar. 23.
A Small Central Station in Nebraska.* Jas. A. Ward. (27) Mar. 30.
Calculation of the Leakage-Reactance of Induction Motors.* I. E. Hanssen. (27) Mar. 30.
The Electrical Power Supply of London.* C. S. Vesey Brown. (10) Apr.

Marine.

Modern Electrically-Equipped Shipbuilding Berths.* (26) Mar. 1.
Improvements in Projectors.* John I. Hall. (26) Serial beginning Mar. 1.
The Deformation of Propeller-Blades.* William Burlingham. (11) Mar. 1.
The Commercial Motor-Vehicle and Motor-Boat Exhibition.* (11) Serial beginning Mar. 15; (73) Mar. 15; (12) Serial beginning Mar. 15.
Safe Submarine Vessels and the Future of the Art.* Simon Lake. (12) Serial beginning Mar. 22.
Propelling and Ordnance Machinery of Warships.* James McKechnie. (Paper read before the Inst. of Naval Archts.) (11) Serial beginning Mar. 22; (12) Serial beginning Mar. 22.
Tendencies and Improvements in Marine Gas-Engine Construction.* Howard Greene. (9) Apr.
Special Types of Hull Construction for Cargo Steamers.* (13) Apr. 4.
Les Turbines à Vapeur.* (From paper read before Soc. d'Encouragement pour l'Industrie Nationale.) (37) Dec., 1906.
Die Aenderung der Umlaufzahl und des Wirkungsgrades von Schiffschrauben mit der Fahrgeschwindigkeit. H. Lorenz. (48) Mar. 2.
Englische und Deutsche Normalprofile im Handelschiffbau. Carl Kielhorn. (50) Mar. 13.

Mechanical.

Cooling Towers.* B. Franklin Hart, Jr. (Paper read before the Amer. Soc. of Refrigerating Engrs.) (8) Jan.
The Royal Observatory and the L. C. C. Power Station, Greenwich.* (Abstract of Report of Special Committee on Vibrations and Chimney-Gas.) (26) Mar. 1; (73) Mar. 1.
Temperley-Cockburn System of Steam Extraction for Water-Tube Boilers.* (47) Mar. 2.
Electric Driving in Textile Mills.* (26) Mar. 8.
Imperial Japanese Government Steel Works at Wakamatsu. (From report by H. M. Chargé d'Affaires at Tokio to the Board of Trade.) (22) Mar. 8.
Condensers and Condensing Plants.* (47) Serial beginning Mar. 9.
Some Notes on Elevators and Conveyors.* W. B. Leech, Assoc. M. Inst. M. E. (Abstract of paper read before the Scottish Jun. Gas Assoc.) (66) Mar. 12.
Modern Equipment in Old Plants; Molding Machine Development at the Foundry of the Falls Rivet & Machine Company.* H. M. Lane. (20) Mar. 14.
The Commercial Motor-Vehicle and Motor-Boat Exhibition. (11) Serial beginning Mar. 15; (73) Mar. 15; (12) Serial beginning Mar. 15.
Thermal Properties of Water and Steam at High Temperatures.* (11) Serial beginning Mar. 15.
New Power Plant of the Potomac Electric Power Co. of Washington, D. C.* (14) Mar. 16.

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Mechanical—(Continued).

Electrolysis of Gas Mains. M. R. Bump. (Paper read before the Amer. Gas Inst.) (24) Mar. 18.
Scraper Excavators.* (13) Mar. 21.
Smoke Prevention in Factories and Electric Supply Stations. John B. C. Kershaw. (29) Mar. 22.
The Effect of Moisture in the Atmosphere upon the Economical Working of Blast Furnaces.* Horace Allen. (47) Mar. 23.
Types of Enclosed Steam Water Heaters.* C. R. Allensby. (Paper read before the Civ. and Mech. Engrs. Soc.) (47) Serial beginning Mar. 23.
High-Pressure Elevator Equipment of the Metropolitan Life Insurance Building, New York.* (14) Mar. 23.
The Nordberg Piston Blowing Engine.* (From *American Machinist.*) (16) Mar. 23.
An Interesting German Flying Machine.* Alfred Gradenwitz. (46) Mar. 23.
Valuation of Gas Oils. A. Spiegel. (Abstract from *Journal für Gasbeleuchtung.*) (66) Mar. 26.
Power Plant of the Sperry Flour Co., Los Angeles, Cal.* W. F. Durand. (14) Mar. 30.
A Large Stone Crushing Plant at Gary, Ill.* (14) Mar. 30.
Hydro-Electric Power Versus Steam for Industrial Plants. H. von Schon. (9) Apr.
Coking Freeport Coals.* J. B. Hanford. (Paper read before the Coal Mining Inst.) (45) Apr.
Modern Gear-Cutting Machinery.* Joseph Horner. (10) Apr.
The Proper Management of Corliss Engines.* W. H. Wakeman. (64) Apr.
Coal Storage and Coal Conveying Systems.* Franz Koester. (64) Apr.
Practical Data from Modern Gas Engines: Fuel, Water and Oil Consumption. L. L. Brewer. (64) Apr.
Making Incandescent Gas Mantles.* M. C. Whitaker. (Paper read before the New England Assoc. of Gas Engrs.) (83) Serial beginning Apr. 1; (24) Apr. 1.
Special Handling Appliances for the Shop.* H. M. Lane. (20) Apr. 4.
An Important Seamless Tubing Decision; the Shelby Steel Tube Company Wins its Patent Suit.* (20) Apr. 4.
Moteurs à Combustion Interne et Machines à Vapeur.* R.-E. Mathot. (37) Dec., 1906.
Expériences sur la Compression de la Vapeur dans l'Espace Nuisible des Machines à Vapeur.* J. Boulvin. (37) Feb.
Recherche et Dosage des Gaz Combustibles; Emploi de l'Eudiomètre à Eau Transformé en Grisoumètre.* Nestor Gréhant. (33) Mar. 2.
Transporteur Aérien de 35 Kilomètres entre Chilecito et Upulungos (République Argentine).* (33) Mar. 23.
Bau und Betrieb der Kupolöfen. C. H. Jaeger. (50) Mar. 6.
Uber die Materialbeanspruchung in Rotierenden Körpern.* Edmund Röggla. (53) Mar. 8.
Neuere Selbstgreifer für Krane und Dergleichen.* F. Wintermeyer. (82) Serial beginning Mar. 9.
Der Dampfturbinenbau der Allgemeinen Elektricitäts-Gesellschaft.* O. Lasche. (48) Mar. 9.
Zur Fabrikation Gezogener Gasrohre.* Anton Bousse. (50) Mar. 13.
Die Gefahrfrage der Paternosteraufzüge für Personen und die Schutzmittel zur Verhütung von Unglücksfällen.* Ad. v. Ernst. (48) Serial beginning Mar. 16.

Metallurgical.

Electrolytic Precipitation of Cyanide Solutions.* Charles P. Richmond. (16) Mar. 16.
The Lead-Smelting Works of Port Pirie.* Guillaume D. Delprat. (16) Mar. 16.
Belt Elevators for Ore and Water.* Edward S. Wiard. (16) Mar. 23.
L'Enrichissement des Minerais Sulfures Mixtes de Broken Hill (Australie).* E. Lemaire. (33) Mar. 9.
Die Bewertung der Eisenerze. M. Drees. (50) Mar. 6.
Ueber die Manganbestimmung bei Anwesenheit von Wolfram. G. v. Knorre. (50) Mar. 13.

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The Armstrong Pozzuoli Works.* (12) Mar. 15.
Latest Designs of the Motor in Warfare.* W. G. Fitz-Gerald. (46) Mar. 23.

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Electrical Coal-Cutting by Bar Machines, with Special Reference to the "Simplex" Machine. Arthur Hall. (Paper read before the National Assoc. of Colliery Mgrs.) (22) Mar. 1.
Endless Rope Haulage.* B. Harrison. (Paper read before the National Assoc. of Colliery Mgrs.) (22) Mar. 8.

* Illustrated.

Mining—(Continued).

Safety in Winding. George H. Winstanley. (Abstract of paper read before the National Assoc. of Colliery Mgrs.) (22) Mar. 15.
The Coal Dust Problem. James Ashworth. (12) Mar. 15.
Electric Power *vs.* Mules for Mine Haulage.* M. F. Peltier. (16) Mar. 16.
Goodman Rack Haulage in Service on Light Grades at Rossiter, Pa.* (From *Electrical Mining.*) (62) Mar. 16.
The Cave-In of an Inclined Shaft and Subsequent Rescue of an Entombed Miner, at Bakersfield, Cal.* F. C. Finkle. (13) Mar. 21.
Methods of Mining in Indiana Coal Fields.* Floyd W. Parsons. (16) Mar. 23.
Mining Anthracite by Longwall.* (45) Apr.
The Old Hundred Mine and Mill.* (45) Apr.

Miscellaneous.

Stream Lines and Their Application to Engineering Purposes.* H. S. Hele-Shaw. (47) Mar. 2.
Light and Illumination. Charles P. Steinmetz. (Paper read before the Illuminating Eng. Soc.) (83) Mar. 15; (24) Serial beginning Mar. 18; (19) Serial beginning Mar. 30.
La Vie et les Travaux de Jean-Rodolphe Perronet.* De Dartien. (43) 1906, Pt. 4.

Municipal.

Automatic Street Lighting.* S. O. Stephenson. (Paper read before the Midland Assoc. of Gas Mgrs.) (66) Mar. 5.
Pipe Subways in British Cities and in Paris.* (13) Mar. 14.
Experience with Various Pavements on Streets with Heavy Grades.* C. G. Anderson. (Abstract of paper read before the Ill. Soc. of Engrs. and Surv.) (13) Mar. 14.
The Method, Cost and Results of Tarring Heavily-Traveled Macadam Streets in Chicago. (14) Mar. 16.
The Illinois Road Traffic.* A. N. Johnson. (Abstract of paper read before the Ill. Soc. of Engrs. and Surv.) (14) Mar. 16.
Oiled Roads in California. (14) Mar. 23.
Some Results of Low-Pressure Incandescent Street Lighting. L. D. Moseley. (Paper read before the Manchester and District Junior Gas Assoc.) (66) Mar. 26.
Macadam Streets Surfaced with California Liquid Asphalt, as Constructed in the City of Redlands, Cal.* C. C. Brown. (13) Apr. 4.

Railroad.

The Anatomy of a Railway Motor and Control Equipment.* James Lyman. (61) Feb.
The Theory of the Design of Railway Freight Terminals.* H. M. North. (4) Feb.
The Track Circuit as Installed on Steam Railways.* H. G. Brown. (77) Feb.
Varnish: the Last Thing Applied to a Car or Locomotive, but not the Least Important. William Marshall. (65) Feb.
The Progress of Electricity on Steam Roads in 1906. Bion J. Arnold. (4) Feb.
Danger to High Speed Trains on Curves.* Richard T. Dana. (87) Mar.
Can the American Method of Putting in Split Switches be Improved?* (87) Mar.
Concentration Sidings at Wath; Great Central R.* Chas. S. Lake. (21) Mar.
Signalling on the Great Northern & City Railway.* (21) Mar.
Rail Motor Cars; Great Northern Railway (Ireland).* (21) Mar.
Eight-coupled (4-8-0 Type) Engines; Londonderry and Lough Swilley Railway.* (21) Mar.
New 4-6-0 Type Engines; Great Central Railway.* (21) Mar.
Method of Relining the Hodges' Pass Tunnel, Oregon Short Line Ry.* (87) Mar.
The Generation of Power at Neasden (Metropolitan Ry.).* (12) Mar. 1.
British-Built Locomotives for Service Abroad.* Chas. S. Lake. (47) Mar. 2.
The Relation of Locomotive Wheel Base to Track Curvature. George R. Henderson. (40) Mar. 8.
The New York Subaqueous Tunnels.* Charles Prelini. (11) Serial beginning Mar. 8.
The Passenger Stations of the Hudson Companies.* (17) Mar. 9.
Electric Car Testing. A. S. Richey. (Abstract of paper read before the New England St. Ry. Club.) (17) Mar. 9.
Battle Creek Shops of the Grand Trunk Ry.* (18) Mar. 9; (40) Mar. 8
Operation and Construction of the Elgin & Belvidere Railway.* R. H. Rice. (72) Mar. 9; (18) Mar. 9.
The Inter-Pole Railway Motor. C. A. Mudge. (27) Mar. 9.
Stresses in Tracks on Curves.* (15) Mar. 15.

* Illustrated.

Railroad—(Continued).

The Bay Shore and Dumbarton Cut-Offs of the Southern Pacific.* (15) Mar. 15.
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PAPERS AND DISCUSSIONS.

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THE REINFORCED CONCRETE BRIDGE ACROSS THE HUDSON RIVER AT SANDY HILL, NEW YORK.

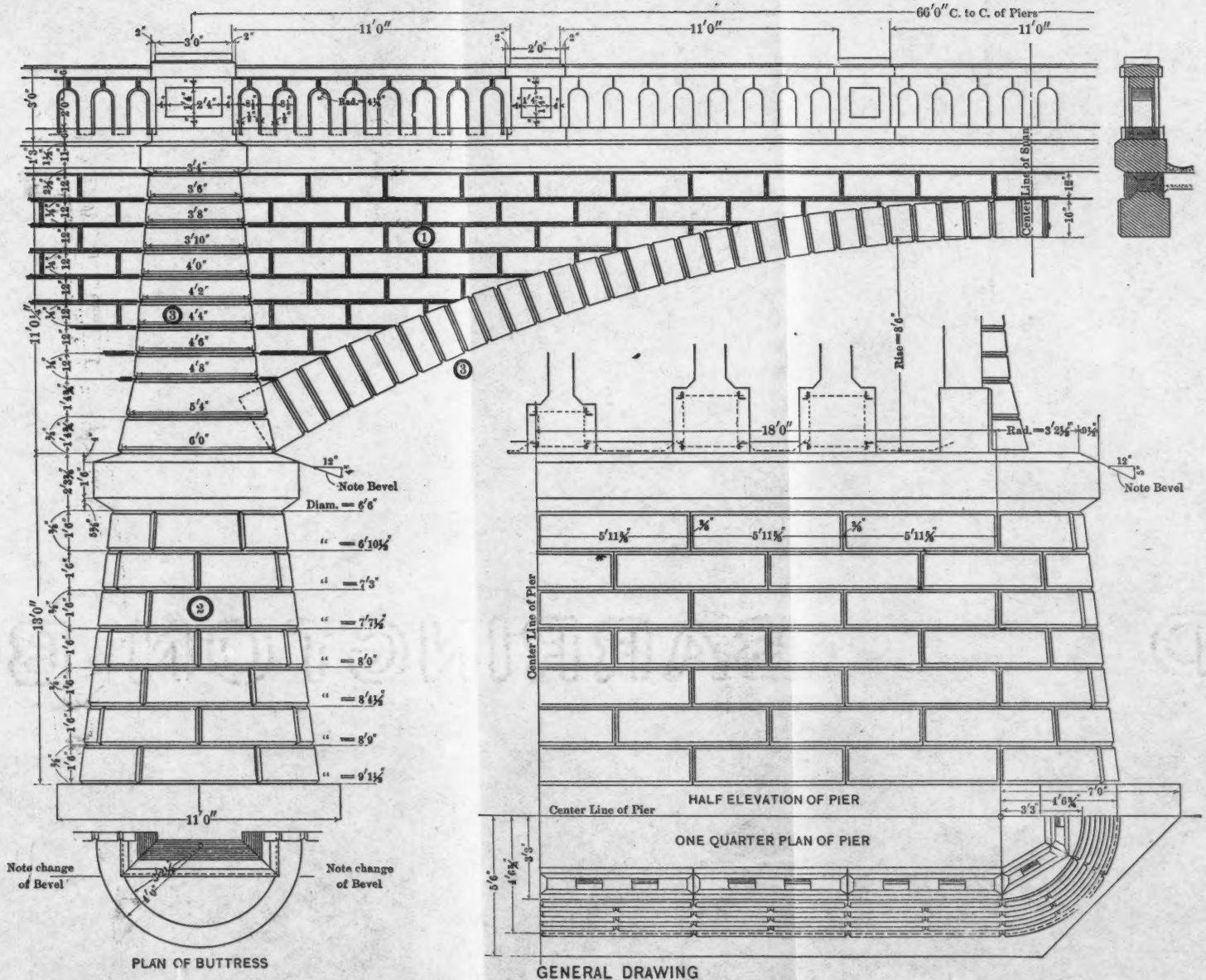
By William H. Burr, M. Am. Soc. C. E.

To be Presented May 15th, 1907.

The bridge across the Hudson River at Sandy Hill, N. Y., is a reinforced concrete structure built jointly by the Counties of Saratoga and Washington and the Union Bag and Paper Company, whose extensive paper and pulp mills are located on both sides of the river in close proximity to the bridge. The structure is to serve for both highway and passenger traffic and for the transportation of materials, either raw or finished, between the mills and the railway tracks on either side of the river.

The width of the bridge, between the outer surfaces of the spandril walls, is 35 ft. 8 in., while the width between the coping stones is 32 ft. The latter width affords room for a roadway 26 ft. 9 in. wide and a 5-ft. 3-in. sidewalk. On one side of the roadway is placed a standard gauge railway track, the center of the nearest rail being 4 ft. 3 in. from the adjacent coping. The railway track is designed for the use of the Union Bag and Paper Company in

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.



GENERAL DRAWING

OF BRIDGE OVER THE HUDSON RIVER AT SANDY HILL, N. Y.
FOR THE COUNTIES OF SARATOGA AND WASHINGTON.

the transportation of its material, to which reference has already been made.

There are fifteen arch spans, each 60 ft. in the clear, the piers being 6 ft. thick at the top between the springing joints of the arch ring, and 9 ft. thick 13 ft. below the springing joints at the top of the foundation mass of concrete. The total length of the bridge and the two abutment walls is 1 025 ft., making, it is believed, the longest reinforced concrete structure in existence at the present time. The radius of the intrados is 57 ft. 6 in. As shown on the plans, the rise of each arch is 8 ft. 6 in. The depth of the ring stones is 18 in. at the crown and 30 in. at the skewback or springing joint.

The spandril walls, as well as the arch ring and the exterior walls of the piers and abutments, are composed of concrete blocks designed with interior open spaces or voids filled with thin mortar or thick grout after being laid in place. These blocks were cast or moulded in wooden forms in a building near the east end of the bridge, and were usually taken out of the forms in from 24 to 48 hours after being cast. Reference to this feature of the structure will be made later.

The railing is also of concrete, the upright members having been cast in forms or moulds in a manner similar to that in which the spandril and other blocks were made, with the horizontal members cast in place.

The main supporting members of each span are five arch ribs, the two heavier ribs being placed under the railway track, each rail being over the center of a rib. The other three ribs are placed equi-distant from each other and from the adjacent railway rib, 5 ft. 10 in. from center to center. Internal spandril walls, each 12 in. thick for the three lighter ribs, and 15 in. thick under the railway track, support a reinforced concrete floor plate or slab 8 in. thick for the entire roadway and 6 in. thick for the sidewalk, the top surface of the latter being 8 in. above the former. The top surface of the concrete is the finished sidewalk surface, but an asphalt pavement, crowned to a thickness of 4 in. between the railway tracks and 2 in. at the gutter, is laid for the roadway pavement, bricks suitably formed being laid on each side of each rail. The outer edges of the sidewalk plates and their

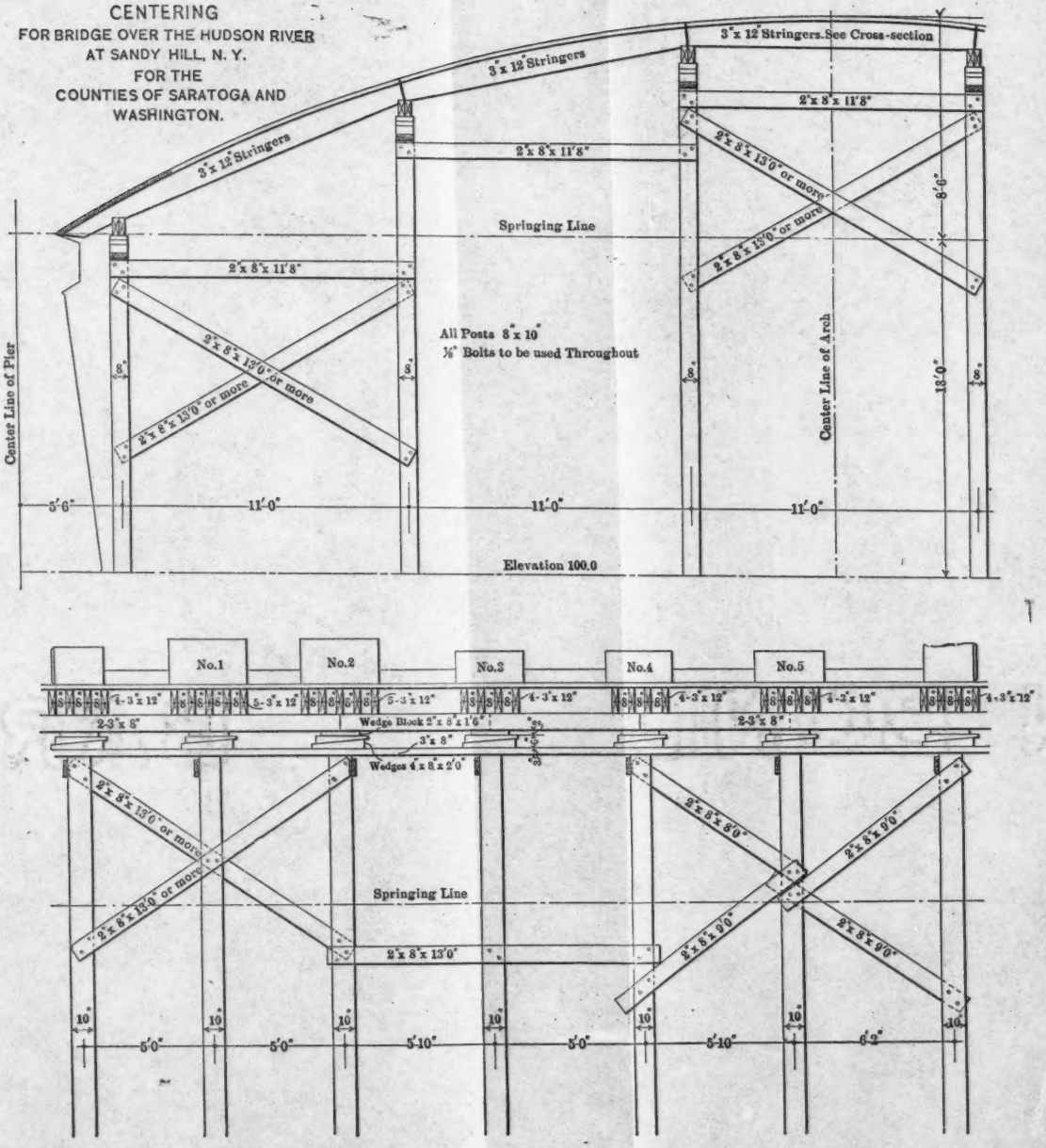
proportionate loads are carried by the spandril walls and the ring stones. The structure is designed to carry its own weight, a snow load of 12 lb. per sq. ft. and a moving load of 100 lb. per sq. ft. over the roadway and sidewalk, while the ribs under the railway track are designed for a moving load consisting of a train of cars, each, with its load, weighing 120 000 lb., carried on two trucks with four wheels each. The reinforced concrete roadway floor plates are also designed to carry a truck weighing 12 tons resting on a wheel base of 10 by 6 ft.

In the computations the modulus of elasticity of concrete was taken at 2 000 000 lb. and that of steel at 30 000 000 lb. per sq. in.

The bridge is designed to carry the preceding loads without exceeding a compressive stress of 500 lb. per sq. in. in the concrete. For all ordinary loadings, even with the railway loads prescribed above, that compressive stress does not exceed about 400 lb. per sq. in. The tensile resistance of the concrete in any part is not taken into account. As shown on the plans, the cross-section of the ribs under the railway tracks is 3 ft. square at the springing joints and 3 ft. by 1 ft. 10 in. at the crown, while the three lighter ribs are 2 ft. 8 in. by 2 ft. 3 in. at the springing joint and 2 ft. 8 in. by 1 ft. 2 in. at the crown. The steel reinforcement of each rib consists of four 3 by $2\frac{1}{2}$ by $\frac{5}{16}$-in. angles embedded in the concrete, as shown on the plans, with not less than 2 in. of concrete outside of them at all points. These reinforced angles are latticed into their proper relative positions by $2\frac{1}{4}$ by $\frac{5}{16}$-in. steel lattice bars. It was found that these reinforcing ribs could not be secured in the shape of ordinary riveted members without great delay and excessive cost, and therefore the steel angles and lattice bars were shipped directly from the mills to the bridge site, where a portable punch, shears and simple bending rolls were improvised. With this simple field outfit, manned by three or four laborers, all the reinforcing steel required for the ribs was laid out, punched, bolted together and put in place. As all this work of fabrication was done at the bridge site, all the work was bolted up, no rivets whatever being used. The plans show how rigidly the steel reinforcement of the ribs was joined at the tops of the piers with a corresponding reinforcement running down to the bottom of the concrete hearting of the piers. By these

CENTERING

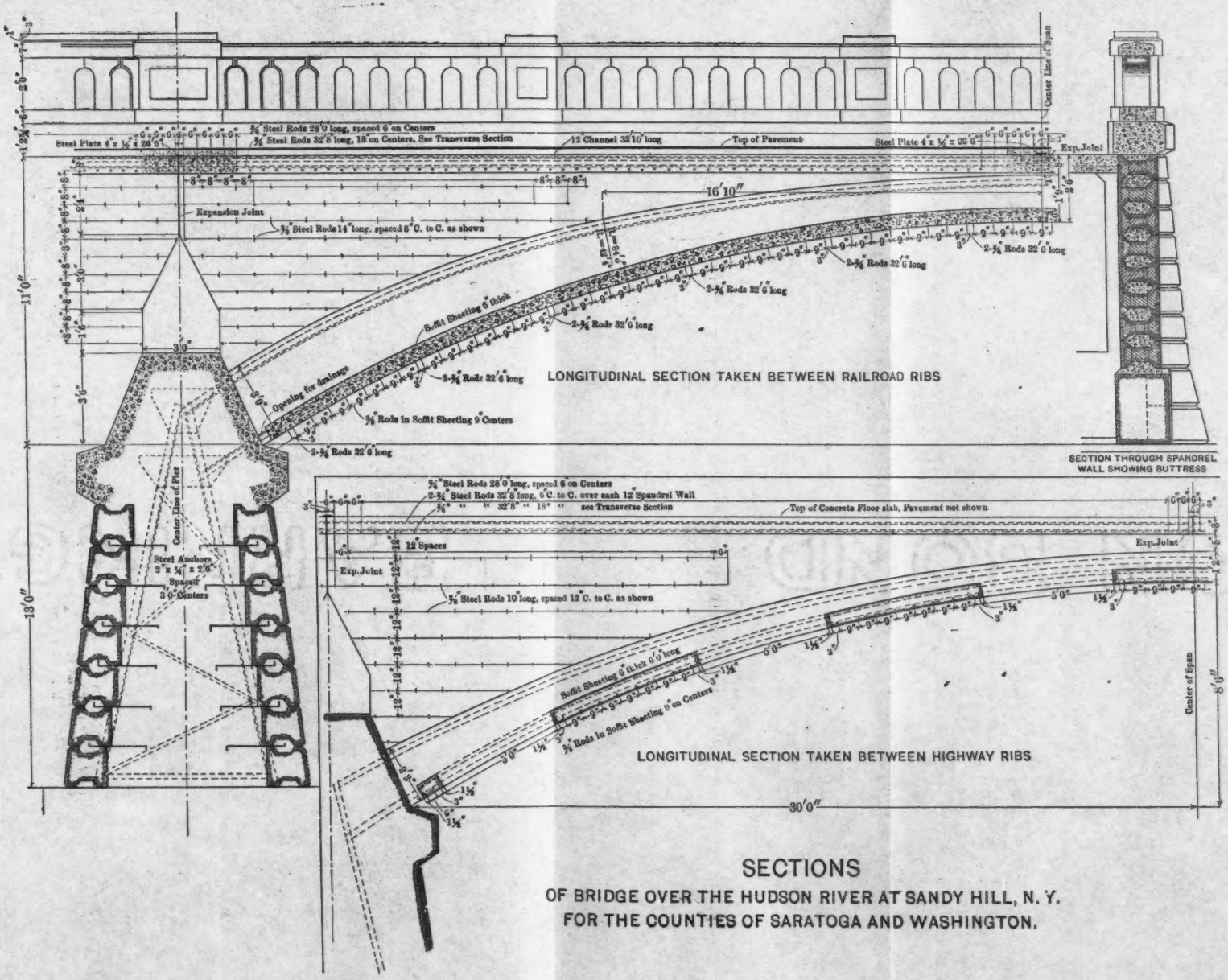
FOR BRIDGE OVER THE HUDSON RIVER
AT SANDY HILL, N. Y.
FOR THE
COUNTIES OF SARATOGA AND
WASHINGTON.



together with the interior spandril walls. An examination of the plans will show that while the structure is essentially of skeleton character, with economical interior vacant spaces, its parts are rigidly bound together in the most positive manner with the steel reinforcement and by continuity of concrete work, the steel being nowhere within 2 in. of the exterior surface of the concrete.

The concrete blocks of the piers and abutments are also rigidly bonded or tied to the interior concrete hearting with the flat steel anchors reaching at least 18 in. into the concrete backing. The piers and ribs, with the steel reinforcement of each, are designed and built so as to constitute a reinforced monolithic concrete mass, insuring a fixedness of the ends of the ribs to the pier with such a bond as to make impossible any sensible movement of one with reference to the other.

The system of designing and casting the blocks forming the exterior spandril walls, arch rings and the exterior walls of the piers and abutments constitutes a most interesting feature of this work, if not its only really novel one. As the plans show, these blocks are formed with interior vacant spaces and with corresponding channels or recesses along their beds and joints. When these blocks, therefore, are laid in place, as in the process of construction, a honeycomb mass with internal channels or open spaces is formed. The outer portions of the horizontal and vertical joints may then be packed with any convenient or economical material such as jute, or any other fibrous material, or paper waste. After thus packing the outer portions of the joints, mortar or thick grout may be poured into the openings so as to fill completely all portions of these interior spaces. It will be observed that the recesses in the blocks and other internal openings were formed so as to insure a thorough and complete filling of every portion of the joints and spaces in the blocks as cast. These recesses or internal spaces can be formed quickly and cheaply by the suitable use of partially filled paper bags of sand, as was done in this case. After the block is set these paper bags are punctured and the sand at once runs out, leaving the desired voids. Furthermore, this process makes every wall thus formed essentially monolithic, resulting in the highest obtainable degree of strength, solidity and water-tightness. After the mortar has hardened, the joints are raked out in the ordinary man-



SECTIONS

OF BRIDGE OVER THE HUDSON RIVER AT SANDY HILL, N. Y. FOR THE COUNTIES OF SARATOGA AND WASHINGTON.

ner and pointed, as in any masonry. These blocks were cast in wooden forms, the concrete for the entire structure being a 1-2-4 mixture. The exterior surface of the blocks is essentially composed of a 2 to 1 mortar. The forms were well made of smoothly-surfaced stuff, although no extraordinary care or skilled labor was used. Carpenters such as were available at Sandy Hill, and who had never done such work before, made the forms or moulds, and local workmen filled them. Although the surfaces of the blocks are not as smooth as could be obtained from metal-lined moulds, and although some are a little pitted, the results are excellent. The general effect of the structure, when observed as a whole, even close at hand, is that of masonry blocks of unusually smooth and regular texture. Experience with this structure shows what highly satisfactory results may be accomplished in this field of engineering construction, with any intelligent local labor when well directed. This is equivalent to stating that reinforced concrete work, either *en masse* or by the use of concrete blocks, is economically adapted to a wide range of construction throughout the country, where neither a high degree of skill in fabrication is needed nor more than the simplest appliances for mixing the concrete and putting it in place.

Although the railing has a most substantial and effective appearance, it will be found on examination to be composed of very simple members. The upright T-shaped pieces were cast in wooden moulds, which, after hardening, were put in place. The top rail was then cast in a suitable wooden form over their tops. Its appearance is in every way satisfactory.

Over each pier and the crown of each arch the roadway and sidewalk plates are cut throughout the entire width between the copings of the exterior spandril walls. The interior spandril walls are also cut at the same points. These openings form expansion joints, and are covered with 4 by ½-in. steel plates. No other provision is made for expansion or contraction throughout the entire structure. The ribs, piers and abutments form a continuous reinforced concrete mass a little more than 1 000 ft. long, without any provision for change of length, due to varying temperature or originating from other sources.

A complete system of drainage is provided in a simple way by

frequent openings in the gutters through the deck of the bridge, permitting rain-water and melting snow to run directly into the river.

As shown on the plans, each rail of the railway track is securely fastened to a 10-in. channel, the flanges of which are embedded in the concrete. Suitably formed vitrified brick are laid on either side of each rail, and against these the asphaltic pavement abuts. The wearing surface of the pavement is brought up to such a height as to fall only a little short of being flush with the top of the rails, so as to make the entire roadway deck available for vehicular traffic when the railway track is not in use.

The cement used for this work was the well-known Ironclad brand, manufactured at Glens Falls, N. Y., about four miles from the site of the bridge. It was delivered and used under the standard cement specifications recommended by the Special Committee of the American Society of Civil Engineers on Uniform Tests of Cement. About 6 000 bbl. were required for the entire work.

The broken stone used was crushed local limestone, the specifications requiring 1½ in. as the largest dimension. The sand was also a local material. The concrete for the mass work of the bridge was all produced by a Smith mixer. The following paragraphs from the specifications show the character of the concrete used for all portions of the work:

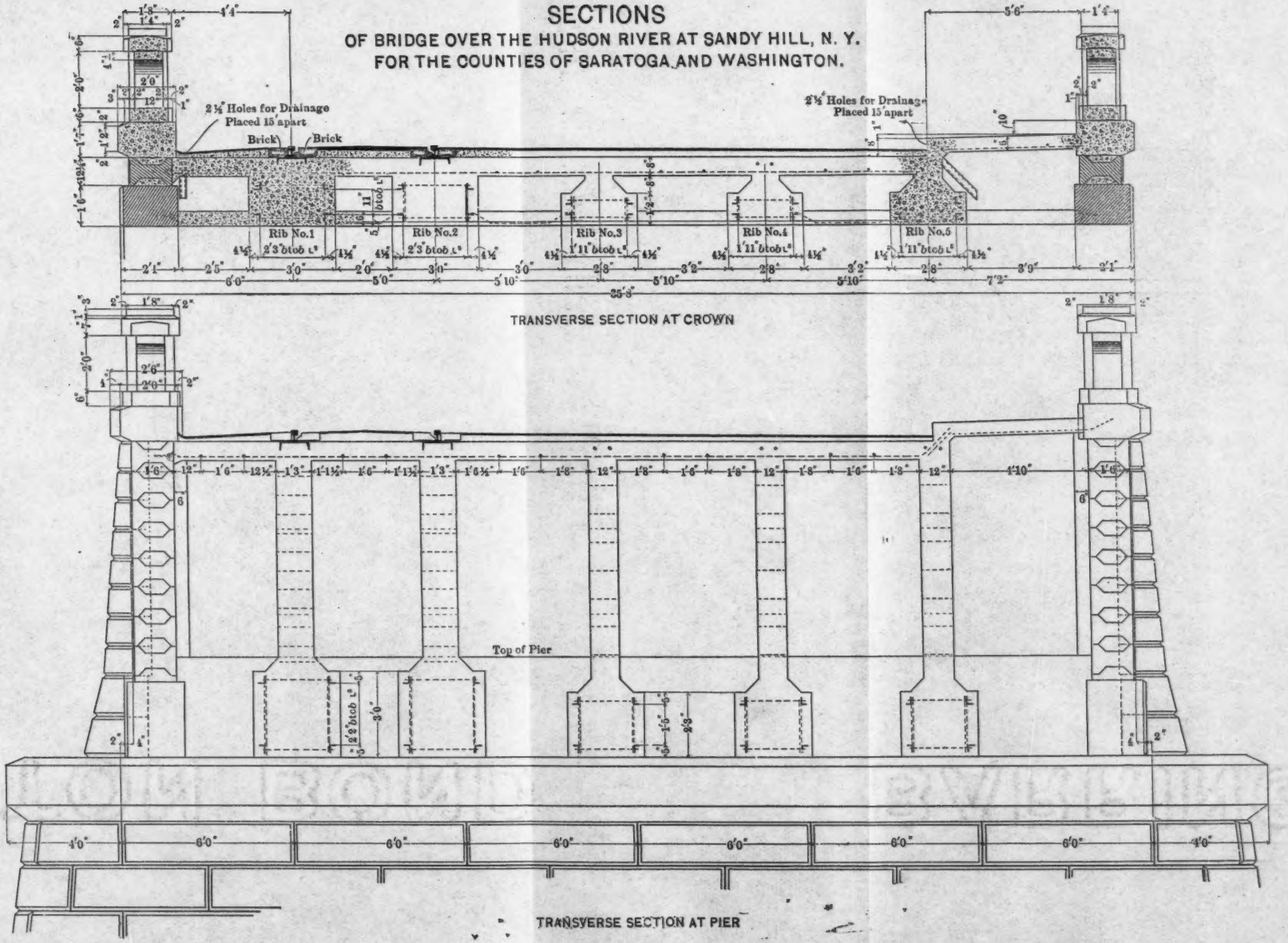
"The concrete for all blocks, for the ribs and the interior spandril walls above them, for floor and sidewalk plates, for the soffit sheets, and for the railings, and for all copings shall be formed of such portions of cement, sand and gravel or broken stone as will make a perfectly solid mass with a little surplus of cement over that required to fill the voids. The proportions of this mixture will be about equivalent to one measure of cement, two measures of sand, and four measures of gravel or broken stone.

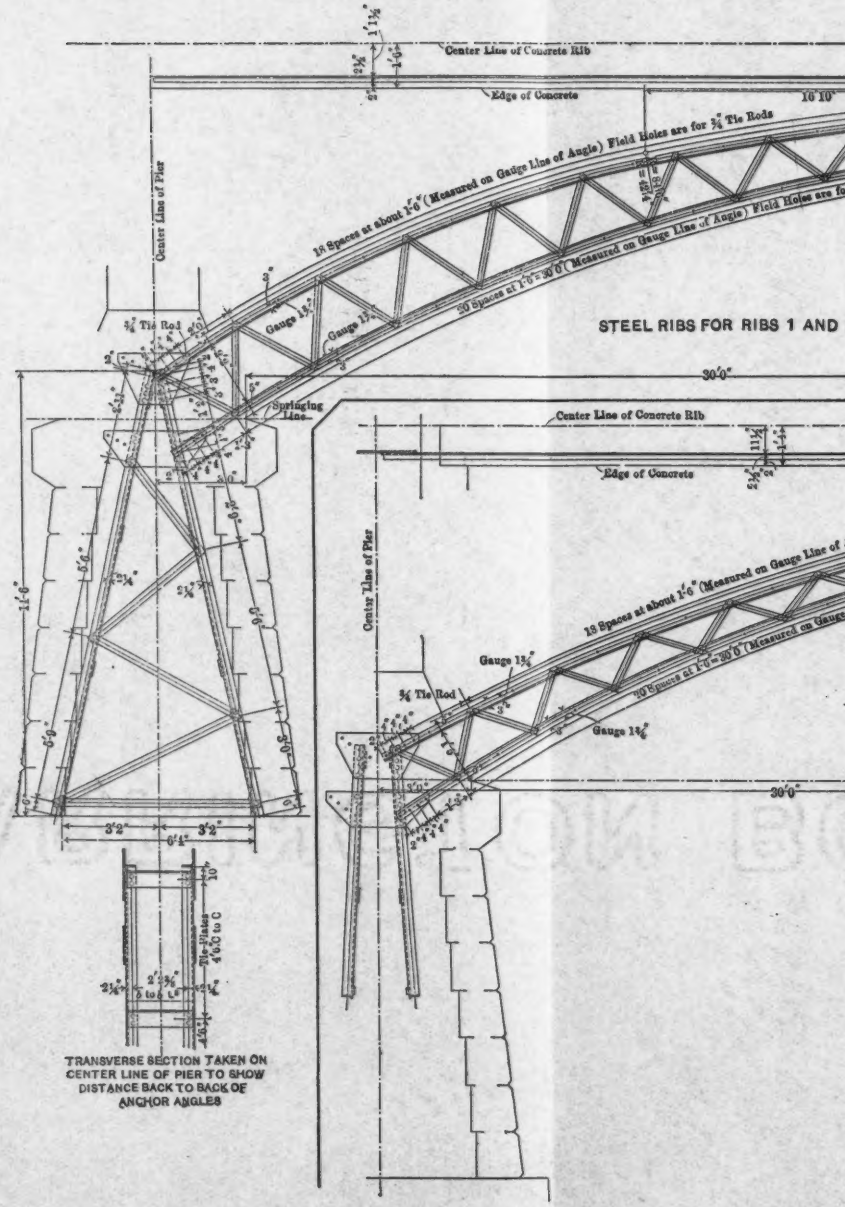
"The concrete for the hearting of the piers, for the footing courses, and for other similar portions of the work, will be of such composition as to be about equivalent to one measure of cement, three measures of sand, and five measures of broken stone or gravel.

"In these provisions for the concrete it is the intention to take advantage of balanced sand, gravel or broken stone, *i. e.*, to use varying sizes for the purpose of decreasing the voids and using less cement to secure the best results. It will probably be necessary therefore to experiment with different proportions of varying sizes of sand and gravel or broken stone in order to ascertain the best

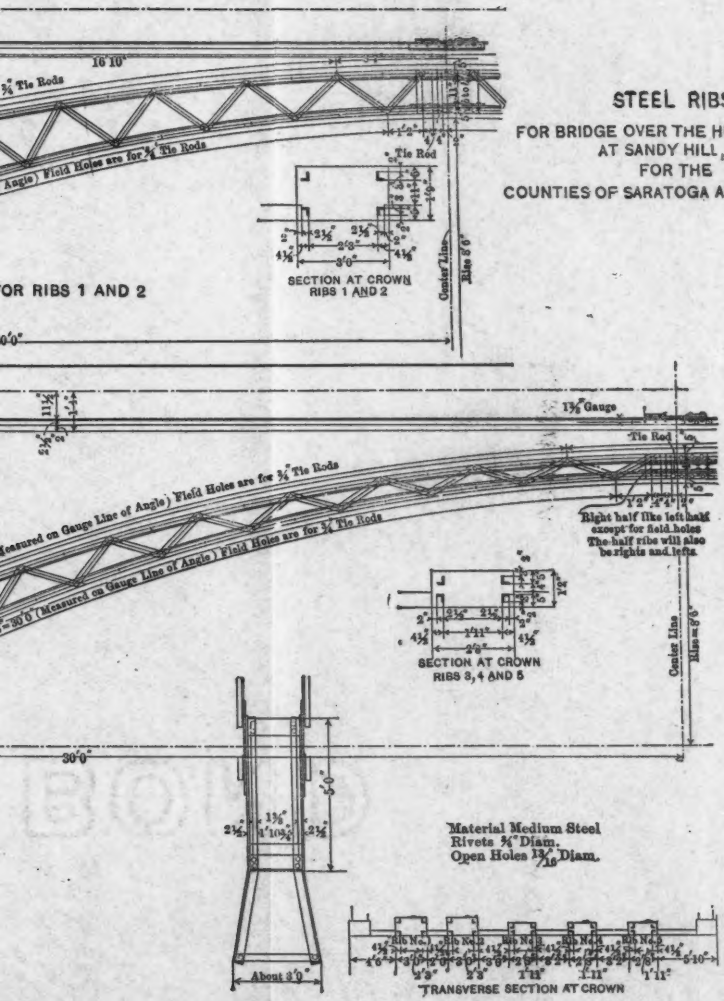
SECTIONS

OF BRIDGE OVER THE HUDSON RIVER AT SANDY HILL, N. Y. FOR THE COUNTIES OF SARATOGA AND WASHINGTON.





STEEL RIBS FOR RIBS 1 AND



STEEL RIBS

FOR BRIDGE OVER THE HUDSON RIVER
AT SANDY HILL, N.Y.
FOR THE
COUNTIES OF SARATOGA AND WASHINGTON



mixture of the available materials at hand to secure the desired ends."

The concrete of the blocks was composed of the finer portions of the crushed material, much of it—especially the exterior portions —being equivalent to about 2 to 1 mortar.

Work on the bridge was begun on May 4th, 1906, and all the concrete work was completed on January 8th, 1907, the total time occupied in construction being 8 months and 4 days.

The total cost of the structure, including the lamp-posts and the resident engineering organization, was about $77 000, about $5 000 of this amount being due to extra labor during nights and Sundays. This extra cost of overtime work was incurred to hasten completion which was imperative in consequence of the dangerous condition of the old wooden bridge, the only available means of crossing the river at this point prior to the completion of the new structure. A little extra expense was also incurred in heating—by use of salamanders—various portions of the work during the extremely cold weather of the six weeks prior to the close of the work. Under ordinary conditions, therefore, the total cost of the bridge would scarcely have exceeded $72 000.

The method of casting the blocks with the internal openings, and the high degree of efficiency displayed in the prosecution of the work, were both due to the Resident Engineer, Mr. M. O. Kasson, who was continuously engaged on it from the beginning to the end of the construction.

The entire work was done by day labor under the charge of the resident engineer.

The method of stiffening the ribs, it will be observed, is practically the Milan system of construction, and it was used under arrangement with the Concrete-Steel Engineering Company, of the City of New York, which company owns the Milan patents.

The river bed at Sandy Hill is practically clean rock with only a little detritus on its surface. During the summer the water is shallow, nowhere exceeding 2 or 3 ft. in depth. The foundation masses of concrete of all the piers, therefore, could be put in place quickly and cheaply within simple coffer-dams involving little time or cost. To this condition is due largely the comparatively short time required for the construction of the bridge and its low cost.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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THE LOWER COLORADO RIVER AND THE SALTON BASIN.

Discussion.*

BY MESSRS. W. G. PRICE, RUTGER B. GREEN AND T. G. DABNEY.

Mr. Price.

W. G. PRICE, M. AM. SOC. C. E. (by letter).—The writer wishes to make the following suggestions as to a form of dam which might be used to close the outlet of the Colorado into the Salton Basin.

Owing to the rapidity with which water sometimes cuts the silt deposit from under a dam, it is not safe to build such dams with piling or with piling driven through a single thick mattress. The cutting away of the silt below the mattress will usually undermine the piling and cause that part of the dam which is supported by piling to be carried away. The dam must be built so that the water cannot move any part of it in any direction except vertically downward. Such a dam must necessarily be built wholly of mattress and ballasted with rock, one mattress on top of another being added as the structure settles, until the water can move it no farther, after which it can be carried to the desired height. By carrying the mattress structure far enough into and on top of the river banks to prevent the water from cutting around it, the work can be completed as rapidly as may be convenient, and without fear of failure.

For closing a channel of a river of the size and velocity of the Colorado, the mattress should be not less than $2\frac{1}{2}$ ft. thick and

*This discussion (of the paper by C. E. Grunsky, M. Am. Soc. C. E., printed in *Proceedings* for February, 1907), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

consist of alternate layers of brush, the layers being laid at right angles to each other and with such distribution as to form pockets about 1½ ft. deep to hold the rock ballast. The mattress must be bound together so that the water cannot cause it to fray out at the down-stream edge and go to pieces stick by stick; and, where the structure is to be permanent, metal must not be used for a permanent fastening of the parts. All fastenings must be of wood, which will not decay under water; metal fastenings will be cut away by corrosion and by the impact of sand particles. No. 10 steel wires laid on the bottom of the Upper Mississippi River by the writer were reduced in sectional area about one-half in 10 weeks by water-driven sand striking them. The wires were taken up and examined every day. They were always bright, and showed no signs of corrosion. The velocity of the water was seldom as great as 4 ft. per sec. Mr. Price.

In building the sill dams in the Atchafalaya River, in 1887, to limit its outlet capacity from the Mississippi River, the writer used a crib form of willow mattress. The Atchafalaya at low water usually carries all the Red River flow, and at flood time its discharge has been more than 400 000 cu. ft. per sec., with a very high velocity.

The foundation for these dams was mostly white sea sand about 80 ft. in depth. The foundation mattress was 304 ft. long, parallel to the river, 3 ft. thick, and each successive mattress had a shorter length. The dams settled many feet as they were being built up, but they stopped settling before they were finished, and they have held against the floods of the Red and Mississippi now for nineteen years.

The writer built one dam, for closing a chute in the Missouri River, on a foundation of very fine sand, and one small part of it settled about 18 ft. before the layers of mattress could be carried above the water surface. A dam built in this way will at first permit much water to flow through it, but dead leaves and other débris, carried by the river at flood time near the bottom, will rapidly choke up the openings between the willows.

RUTGER B. GREEN, M. AM. SOC. C. E. (by letter).—This paper is a very valuable contribution, as it gives an opportunity to witness more geology in a year than usually occurs in an epoch. It is to be hoped that the author will contribute other papers of this kind, for when the immensity of the general situation is considered, it seems probable that the future may direct less scrutiny to the builders of the Imperial Canal and more to the whole problem. Mr. Green.

If there were records showing, for centuries back, the efforts of the great floods of this water-shed to find an outlet through the

Mr. Green. silt-choking mouth of the Colorado River, it is possible that they might show that the Imperial Canal merely pricked a bubble that was ripe to burst, and it is well that the present difficulty comes now as a warning instead of years hence when the damage might be a hundred-fold greater. Geology shows that at least once before our historic period the Colorado River may have so choked with silt its outlet at the sea that its floods, backing up under the increased friction, filled this Salton Sink 20 ft. above present sea level, and then under the increased head flushed out their outlet to the Gulf of California. Apparently, this present Colorado Desert may have acted as an automatic flush-tank on a by-pass with silt valves.

That there have been occasional overflows of the flood waters of the river into this basin in very recent years would indicate a possibly rising river level and gradually approaching danger. Mr. Grunsky states that small channels, cut through the river's bank by recent floods, have subsequently choked themselves by depositing driftwood and silt against the mass of vegetation that springs up in the channels. Admitting that Nature has apparently done an immense amount of very permanent construction in just this frail temporary-looking style, still, considering the power of the floods and the quantity of silt they bring down to choke their sea outlet, it does not seem impossible that in this particular case her work was not intended to be permanent, and that the present trouble would have come merely a little later if the Imperial Canal had not been cut.

It is to be hoped that the magnitude of the interests at stake will induce the United States Government, either with or without Mexican aid, to make systematic records and studies of the whole situation, so that the engineers of the future may have suitable information to guide them in the work that evidently lies waiting for them.

Mr. Dabney. T. G. DABNEY, M. AM. SOC. C. E. (by letter).—This paper is extremely interesting and instructive. The complete manner in which the entire subject has been presented is evidence that the author was thoroughly equipped for the task.

It appears that, on November 4th, 1906, after most heroic efforts, the work of closing the outflow from the Colorado River was accomplished, which, in view of the difficulties encountered, was a most notable achievement, reflecting great credit on the engineer who directed the work.

Some brief reflections are here offered on the cause of the failure of the enterprise. The most impressive feature is the apparent insignificance of the agency which caused such a great disaster, reminding one of the fable in which the mouse gnawed through the cords which bound the lion.

Mr. Dabney.

It would seem that the integrity of the main structure was dependent on the maintenance of a comparatively inconsiderable levee, extending above and below the dam across the diversion channel. The height of the levee is not stated, but it may be inferred that it was not great. The crown width was 10 ft., with side slopes of 1 on 2. On the Lower Mississippi River the minimum levee section has a crown width of 8 ft., with slopes of 1 on 3.

The failure of the levee was evidently not due to weakness of structure, as the depth of water against the embankment was only 5 ft. The disaster was caused by weakness of foundation, which was emphasized by a borrow-pit on the "land side" of the levee. The depth of the excavation is not stated.

It appears that a grave error was made in excavating for material on the "land side" instead of on the "river side" of the levee, an error which, doubtless, was recognized by the engineer-in-charge after the break.

There is no allusion to any excavation for foundation under the levee, and, from the writer's observations of methods of levee building in California, it is probable that this precaution was omitted. In the writer's practice in levee building, such an excavation is deemed indispensable. It is called, in the vernacular, a "muck ditch," and its size varies somewhat according to conditions, but the standard section is: top width, 12 ft., bottom width, 8 ft., depth, 7.5 ft. The excavation and refilling are done with teams and scrapers, the material for refilling being selected where practicable. Had such a "muck ditch" been excavated and carefully refilled, and had the borrow-pit been located on the "river side," is it not probable that this great disaster would have been averted?

There is no information as to whether remedial measures were applied after the weakness of the levee foundation developed, or whether there was sufficient time for such application. Under similar circumstances, along the Mississippi levees, the readiest and most obvious method of combating such danger is by ponding water, over the orifice of the underground flow, by a ring of earth-filled sacks surrounding the escaping water. In this way the velocity head is reduced, and the displaced material is prevented from being washed away. If sacks are not at hand, a "hoop" of earth is built, with a spillway of boards.

If the defective region is too extended for this treatment a dam, or "sub-levee," may be thrown across the borrow-pit on either side of the dangerous locality, with perhaps a "curtain" in the rear of the pit, connecting the cross-levees in order to increase the depth of the ponded water.

Of course, in the case under discussion it is conceivable that the action of the destructive agencies may have been too precipitate to admit of any remedial measure being taken, and it seems probable that this was true.

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MOVABLE BRIDGES.

Discussion.*

BY MESSRS. C. R. DART, J. R. WORCESTER, ALBERT HENRY SMITH, H. D. HESS, J. E. GREINER AND MARTIN GAY.

Mr. Dart. C. R. DART, M. AM. SOC. C. E. (by letter).—For several years the writer has been connected with the construction of bascule bridges on the Chicago River, and, possibly, a few notes from his experience may be of interest.

The question of the best type of bascule bridge will not be discussed, the subject being too comprehensive for the time available and too dangerous to open. It will suffice to say that there are several types, patented and unpatented, and that each is the very best and cheapest. The variety to be adopted of any type (through, half-through or deck trusses, plate girders or riveted trusses, single or double leaf, etc.), must be decided in accordance with the conditions at the site. The single-leaf bridge is preferable to the two-leaf bridge, when practicable. Counterweight pits below the water level should be avoided, if possible, but when they are necessary, as, for instance, in the case of highway spans, the dirt from the roadway of the movable leaf should not be dumped into such pits.

Regarding the balancing of bascule leaves, the earlier trunnion bridges in Chicago were designed with the center of gravity in front of and above the trunnion, necessitating pneumatic buffers at each end of the travel. According to the later practice, the leaves

*This discussion (of the paper by C. C. Schneider, Past-President, Am. Soc. C. E., printed in *Proceedings* for February, 1907), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Dart.

are balanced as accurately as possible, so that, with no wind, they are stable in any position. Under these conditions, wooden bumpers are used, and have given no trouble.

The center lock now used for two-leaf spans is either a sliding bolt, moved by a motor working in one direction only, as suggested by the author, or consists of rigid tongues interlocking automatically as the leaves close, and having no movable parts.

One of the largest items of maintenance for bascule bridges carrying heavy highway traffic is the cost of floors on the movable leaves. The ideal wearing surface would be a 3 or 3½-in. creosoted wooden block pavement, if satisfactory means could be devised for securing such a pavement in place. Several designs have been submitted, but none has been considered worthy of trial. Where the traffic is light and the wear inappreciable, oak plank is probably the most suitable, as it will last for many years, when ventilated and drained properly. The quality of oak obtainable is rapidly growing poorer, however, and good white oak is becoming more expensive each year. The City of Chicago is using, with considerable success, a patented pavement consisting of 1-in. elm strips on edge, dipped in asphaltum and bolted together into sections containing from 5 to 10 sq. ft. This pavement wears well, and, thus far, has shown little tendency to decay.

The roadway of the fixed parts of a bridge, or of swing bridges, does not present such a difficult problem, as the engineer may choose from a number of well-tried pavements.

For the sidewalks on the movable leaves, 2 by 4-in. hardwood (maple), laid with ¼-in. to ⅜-in. open joints, has been found satisfactory. Where navigation traffic is large, wooden sidewalk stringers should be preferred, for, when struck by a boat, the damage or distortion in the structure will be confined to the point of injury, and can be repaired by carpenters readily and quickly; with steel stringers, several panels of sidewalk may be pulled out of position, and the sidewalk brackets for some distance away may be bent.

Many specifications are lacking in definiteness as to the quality of the lumber desired. The old-time requirement, which has been copied and re-copied for years, specifies all heart lumber, and can no longer be filled. This fact should be recognized by naming a definite grade of lumber, which can be obtained on the market, in accordance with a stated well-known commercial inspection. This is but fair to the contractor, as it gives him a basis for estimating and for purchasing his material.

Regarding machinery, one of the writer's greatest troubles has been to obtain properly fitted keys. The impression seems to prevail, in machine shops generally, that a bridge engineer has no idea of the refinements of engine and machinery practice, and that

Mr. Dart. almost any kind of workmanship is good enough for a bridge. It seems, also, that in many bridge shops it is absolutely impossible to obtain accurate work. The fitting of keys is always a slow and laborious task, running high in shop cost, and it will be slighted, if not carefully watched. Unless keys are accurately fitted for full side bearing, they are certain to work loose.

All machinery for bridges which are moved frequently should be inspected daily, and all keys should be tested and driven tight when necessary. Neglect of this precaution may result in the loss of gears, and a tie-up of the bridge.

In the design of machinery, particular stress should be laid on the requirement of accessibility for inspection and repairs, with especial attention to the matter of space for driving and tightening the keys and for their withdrawal without the necessity of removing an entire shaft with its gears. It would hardly seem necessary to caution a designer on this point, yet it is one which is very often overlooked, and is an important factor in the expense of machinery maintenance.

In his paragraph on toothed gearing, the author requires that all cast pinions shall be shrouded. An alternative method of reinforcing pinion teeth is to increase the face, and, in most cases, the writer considers this method preferable, as cleaner castings can be obtained with a better opportunity for examining the teeth and chipping them, if found untrue. The teeth of slow-moving gears can also be strengthened by reducing their height, and, in the case of pinions which make only two or three revolutions during an operation of the bridge, the tooth height can be cut down to one-half the pitch, since the wear on such parts is inappreciable. Of course, this cannot be done on a twelve-tooth pinion, the minimum limit set by the author.

It is the writer's practice, and a practice which is, he believes, quite general, to increase the thickness of the teeth of pinions engaging racks at the expense of the rack teeth. A very large addition to the strength of the pinion teeth can be thus obtained and the rack teeth will still be the stronger of the two. Breakage should, of course, occur in the pinion—the part most easily replaced—rather than in the rack.

A minor consideration in connection with the machinery is the question of grease cups. Iron cups are generally preferable, as brass cups are a great temptation to thieves. The writer knows of no iron cup on the market, however, which is fully satisfactory. He has found it necessary to add a leather packing in order to prevent the escape of grease around the plunger of the cup.

As to electrical equipment: In the author's specifications only direct-current motors are considered, whereas it is often found that

only alternating current is available. As existing alternating current motors are deficient in starting torque, they are not suitable for operating structures of some size, and it is to be hoped that a satisfactory motor will soon be designed, or an arrangement devised, for operating with these motors. The writer is informed that railroad draw-spans of moderate size are operated in this way at the present time, but, probably, in these cases, the operations are not frequent. When two motors are necessary, the difficulties are increased, as induction motors cannot be operated in series. Mr. Dart.

The question of automatic control for electrically-operated bascule bridges is a debatable one. It is practically impossible to make the control absolutely and reliably "fool-proof," as contacts for cut-outs and limit switches are continually getting out of order, especially if exposed more or less to the weather. If the contacts fail only once a year, such failure may result seriously. Any system of complete automatic control will lead to carelessness on the part of the operator, and a failure of any of the complicated parts of such control to act might cause an accident. If the control is designed so that the bridge will not operate in case of failure, the structure may be tied up at the busiest time of the day, with a possibility of damage suits on account of delays to traffic. The writer, therefore, does not advocate full automatic control, but prefers a simple system of limit switches which will act only when the safety points are passed, and, having acted, require some extra work on the part of the operator to close the circuits.

For bascule bridges with two leaves, it is a wise provision to have the submarine positive-power cables in duplicate, but with only one return cable. Of course, it is also advisable, where possible, to have two independent sources of power, with the wiring arranged so that both leaves can be operated with current from either source. The not infrequent interruptions of power in some localities often make such an arrangement imperative.

In specifying cables, the exact size required should be stated, as there seems to be a wide difference in contractors' figures as to their carrying capacity. The least that should be done is to mention some definite code or wire tables, but an exact specification of size will save many disputes between the contractor and the engineer.

In the paragraph referring to safety gates, such gates are called for in bridges which leave an opening in the floor when the bridge is open for navigation. In cities with heavy street traffic across a bridge, gates should always be provided for the purpose of stopping the traffic, and they should most certainly be provided where an opening in the floor occurs during the operation, even if such opening is closed by the leaf when in its extreme raised position.

Mr. Dart. Gates should be arranged so that each one can be operated independently of the other, and in any order desired, and in no case should they be operated automatically by the movement of the bridge.

The writer desires to give credit to the Bridge Department of the City of Chicago for many of the ideas here advanced, as it is through the operation of the bridges by the city that such ideas have been developed.

Mr. Worcester. J. R. WORCESTER, M. AM. SOC. C. E. (by letter).—This paper is so comprehensive that it would be surprising if a few inaccuracies had not crept in, and it is to be expected that there will be many differences of opinion in minor particulars. It is much easier to criticise than to construct, and the presentation of such a complete treatise on the subject affords the Society an invaluable opportunity to collate all the divergent ideas of its members. With this end in view, the writer submits the following suggestions:

In speaking of jack-knife draws, the author says: "When the bridge is closed, one end of each girder rests on the shoe at the abutment, while the other end rests on the pivot." This is not usually the way these bridges have been built in the vicinity of Boston, where many have been used for the last half century. Although the type has the manifest objection that no ties can be used under the rail, it has been used so extensively, and—as far as the writer knows—with no accident due to this lack of ties, that, perhaps, it deserves a more complete description.

The regular form consists of a deck truss under each rail, one or more needle-beams under the trusses near the free end, and a gallows-frame located over the pivots, braced and anchored back on the shore, to which the ends of the needle-beam are connected by cables. The trusses are generally in the form of wooden Howe trusses with unusually wide chords, but, in a few instances, steel Warren trusses have been used. The trusses are of unequal lengths, with the pivots at different distances from the face of the abutment, so that, when the bridge is opened, the trusses will lie side by side over the abutment, the shortest being next to the abutment and the longest against the parapet. When the bridge is closed, the trusses are arranged to bear not only upon the pivot and the opposite abutment, but intermediate support is obtained at the face of the abutment upon which the pivots are located.

The needle-beams are hinged to the trusses by vertical pins at equal distances from the pivots, and hence are not parallel to the abutments. They are long enough so that the cables attached to their ends will give a proper clearance for the train, and strong enough to carry the dead weight of the bridge.

The cables at their upper ends are connected to the short ends

of the levers hinged on the gallows-frame, and arranged so that, by pulling down the long end, the bridge is raised from the abutments. The connections between the cables and the levers are in the same vertical plane with the pivots, and spaced so that the cables lie in vertical planes. In fact, all the vertical hinge joints are carefully placed to produce parallel motions of all parts. The most difficult parts to arrange for this parallel motion are the ties between the trusses. These must be hinged on the center line of the truss, and, in order to allow the necessary swing for the ties so that the trusses may be closed up together, the ties have to be made with bent ends—**S**-shaped—which, of course, seriously affects their strength. Mr. Worcester.

The bridges are usually operated by a straight rack attached to an arm, hinged to the bottom chord of the longest truss and carried past a pinion on a vertical axis placed on the abutment.

The writer cannot agree with the author's recommendation, in the paragraph on "Rack and Track," that in any case the rack and track "shall preferably be cast in one piece." The rack is much more likely to be injured accidentally than the track, and should always be arranged so that a segment can be replaced without disturbing the track. Should not the specifications also provide that the patterns for special gearing, such as racks, should be furnished with the bridge, so that broken parts can be easily replaced?

An important provision with regard to bascule bridges when in two leaves, is that the ends shall be provided with latches of sufficient strength to transmit enough shear from either leaf to the other in order to equalize the deflection under any condition of loading. This provision might well be introduced in the paragraph on "Bascule and Lift Bridges."

ALBERT HENRY SMITH, ASSOC. M. AM. SOC. C. E. (by letter).— The presentation of this interesting subject by Mr. Schneider will, no doubt, be fruitful of much additional information. Mr. Smith.

It is a pleasure to read a set of specifications which covers the subject so completely and in such a satisfactory manner. The writer respectfully wishes to confirm and add to some of the data presented, and will class his remarks under the several headings given in the paper.

Selection of Design.—The writer believes that, like many another new idea, the bascule idea is and has been overworked, and that such bridges are frequently built where they are not needed, thus causing an excessive first cost and high operating charges.

In addition to the three conditions mentioned by the author as precluding the use of a swing bridge, the following two conditions should cause the consideration of a bascule bridge:

1.—If the protection pier of a proposed swing bridge will render valuable dock property useless;

Mr. Smith. 2.—If the bridge is to be located where the traffic over it is very heavy, and the bridge has to be opened very often, say more than twenty-five times a day.

This second condition may be very important, on account of the time saved in operating a bascule as compared with a swing.

Rim versus Center-Bearing Types.—The points in favor of the center-bearing bridge are all well taken, and are borne out by the writer's experience.

Until recently, the bridge designers of the Middle States have given the rim-bearing type the preference. Ten years ago, in Cleveland, Toledo and Chicago, there were very few center-bearing bridges. Since that date the bridges built in these places have been of the center-bearing, combined rim and center-bearing, and bascule types.

The only objectionable member in a center-bearing bridge, from the shop superintendent's point of view, is the center or pivot casting. This, for bridges approaching 1 000 tons in weight, becomes quite large in diameter, and somewhat difficult to machine.

In the rim-bearing type, if designed in accordance with good practice, it usually works out that the number of rollers required is about as many as can be placed under the drum.

The matter of using plenty of rollers is an important one. In very few bridges of this type do all the rollers carry their proper share of the load, and the writer has seen many of these bridges in which not more than two-thirds of the rollers were carrying any load, the remainder not being in contact with the drum at all, and sometimes three or four consecutive rollers being entirely free.

It is a very difficult matter to get truly conical surfaces for faces or treads for the drum and the track, and equally difficult to get the bottom track properly set in the field. In such cases, everything is in favor of the single pivot; it is machined as a unit and erected as a unit, and there is but one place for the load to go.

The working loose of center pivots of partly rim-bearing swing bridges is quite common. Of the two methods suggested for preventing this, the writer prefers the second—that of rigidly connecting the center to the circular track by radial struts. This not only assures a rigid pedestal, but is an aid to the erection in getting the track circular and concentric with the center pivot.

The combined rim and center-bearing type costs more than the purely rim-bearing type, due to the increased cost of the pivot, radial girders and transverse girders, and, aside from the point in its favor of fixing the center pivot, has nothing in particular to commend it. The detail suggested for the live-ring is a good one.

Mr. Smith.

Of the thousand and one devices used for end lifts, the wedge is by far the most reasonable and satisfactory. The proper shaping of the wedge and its seat provides a most satisfactory means of bringing the bridge into alignment and keeping it there, independent of the latch-pin.

Power Required to Operate Movable Bridges.—For mechanically-operated bridges, a safe rule for the amount of power is to allow 1 h. p. for each 15 tons of weight to be swung. This provides ample margin for taking care of excessive wind pressures, and gives plenty of power to open and close the bridge rapidly. For bridges of 300-ft. span, the gear ratios should be such that the bridge can be opened in 1 min. from the time the ends are unlatched and released.

The foregoing rule has been checked repeatedly by ammeter readings taken on electrically operated bridges, the swinging weights of which have varied from 300 to 1 000 tons. Readings on these bridges show a power reserve sufficient for all possible contingencies. It is usually desirable to open and close a bridge with as little delay as possible, and this can only be done by having ample power to furnish a heavy starting torque.

The effect of wind pressure on an equal-armed swing bridge has often been observed by the writer. Both observations and tests confirm Mr. Schneider's statement, that it may take twice as much power to operate a bridge on a windy day as in calm weather.

Concerning the use of a brake on electrically operated bridges, the writer has always made this a part of the equipment, and he has noted that the bridge operator always uses it to check and control the speed of the bridge when the current is cut out, it being a great aid in stopping the bridge exactly at the latching point. This brake is attached to a shaft, as close to the motor as possible, and is arranged so that it is applied by means of an adjustable weight which is controlled by a foot-lever, the object being to prevent the operator from setting up the brake so hard as to wreck the machinery. The connection between the foot-lever and the brake weight can usually be made by the use of flexible wire rope and pulleys.

The writer prefers the electric motor to the steam or gas engine, if a reliable source of electric current is obtainable. If possible, current should be brought to the switch-board from two independent lines or sources, so that in case one line is dead, the other will be available, the chances of both lines being dead at the same time being very small.

If the bridge is operated very frequently, the electric equipment should be in duplicate. Each motor should be operated by

Mr. Smith.

its own controller, or both motors by one series parallel controller, each motor being of sufficient capacity to handle the bridge independently of the other. With this arrangement, the possibility of not being able to operate the bridge at any time is very remote.

The writer has in mind an electrically-operated bridge with but one source of electric current. The current failed just as the operator was opening the bridge, and the bridge and piers were damaged seriously by the approaching vessel. It was at first proposed to remedy this by installing on the bridge a storage battery of sufficient capacity to operate it three or four times. This was not done, but connection was made to an independent line.

One point of design is frequently overlooked, or not properly taken care of, and that is the brackets and bearings for the rack pinion shaft. Usually, these brackets and bearings are made entirely too light. An examination of about 40 swing bridges, a few years ago, showed that repairs and reinforcement had been made at this point on nearly every one. This is particularly true of power-operated bridges. These brackets and bearings should be designed, not simply strong enough to withstand the strain due to opening the bridge, but to withstand the maximum possible torque that the motor, engine, or brake can develop. The brackets should preferably be steel castings, cast in one piece.

For bridges operated by hand power, it usually develops that one man, using a force of 40 lb. on the hand-lever and moving at the rate of 200 ft. per min., can swing 150 tons of bridge through 90° in 5 min. Hand-operated bridges rarely weigh more than 300 or 400 tons, and two men can open such a bridge in 5 or 6 min. Tests made on rim-bearing bridges of the poorest design confirm the statement that this amount of power is ample.

Concerning the amount of power to be assumed in calculating the strength of gearing, the writer would suggest that, in addition to the power of one man being taken at 125 lb., one should multiply that weight by a number equal to as many men as it is possible to place at the hand-lever.

The writer has seen pinions, amply strong enough to swing the bridge, have their teeth all stripped from them when the first attempt was made to open the bridge in the spring. The bridge would not move, and additional men were asked to lend a hand until something did move.

Materials.—It is noted that cast steel may be used for wedge bearings, and that steel on steel for sliding surfaces is not to be desired. Has anyone ever had any trouble with cast iron sliding on cast steel, when used for wedge surfaces?

It is noted that Mr. Schneider has a strong objection to the use of bevel gearing, and the writer hopes that additional infor-

mation will be given. He has never had any trouble with cast bevel gears, except where the ratio between the pinion and gear was unusually large. Mr. Smith.

H. D. HESS,* ESQ. (by letter).—The very general acceptance of Mr. Wilfred Lewis' discussion of the strength of gear teeth† would make the adoption of his formula seem desirable in specifications like Mr. Schneider's. Mr. Hess.

Bach's formula applies correctly only to the discussion of pinions with from 10 to 12 teeth, while Mr. Lewis' formula applies, with equal accuracy, to gears with any number of teeth. Where the gear ratio is considerable, and an analysis of the pinion tooth only is required, Bach's formula is all that can be desired; on the other hand, when an analysis of the gear tooth is required, as, for instance, with a shrouded pinion, or where the pinion and the gear are of different materials, or where the pinion has a large number of teeth, then Bach's formula fails.

Mr. Lewis' formula, when applied to 15° involute teeth, is of the same form as that given in the specifications, except that $y = \left(0.124 - \frac{0.684}{n}\right)$, where n is the number of teeth on the pinion or gear under consideration.

The fiber stress is reduced as the speed of the gears increases; Mr. Lewis recommends that the fiber stress be reduced according to the formula, $\left(\frac{600}{600 + V}\right)$, where V is the linear velocity, at the pitch circle, in feet per minute. This is in close accord with the factor given in the specifications, $\frac{10}{\sqrt{V}}$.

In general, for "cut" gears, the pressure can be assumed as distributed over the entire width of the tooth. Cast gears and "cut" gears in which the support is likely to be deflected sufficiently to cause the tooth pressure to act at the corners, should be limited to a face width of from one and one-half to two times the circular pitch.

J. E. GREINER, M. AM. SOC. C. E. (by letter).—The writer recently had occasion to make some tests on the power required to operate a double-track swing bridge, and submits herewith the data and results as a contribution to the discussion of Mr. Schneider's most excellent paper. Mr. Greiner.

The bridge tested was the Baltimore and Ohio Railroad double-track swing bridge crossing the Calumet River, at Chicago, Ill.

Total length	250 ft.
Width, from center to center of trusses.	28 "

* Assistant Professor of Machine Design, Cornell University.

† *Proceedings*, Engineers' Club of Philadelphia, 1893, p. 16.

Mr. Greiner.

Angle	90 degrees.
Pitch diameter of rack	34 ft. 2 in.
Center pivot—diameter of disk	2 ft. 0 in.
Total load on pivot—bridge swinging	1 240 000 lb.
Operating Power	Two 50 h. p. General Electric motors, Class 57; efficiency, 85%; rated speed, 470 rev. per min.; 500 volts, direct-current.

The bridge revolves on a center pivot which carries the entire dead load. When under traffic, the load on the center pivot is partially relieved by a wedge arrangement which supports the center cross-girders. The ends of the bridge are raised by jacks instead of wedges, these jacks being operated by toggles arranged so as to convert a horizontal motion to a direct vertical lift.

The tests, which were personally conducted by W. R. Edwards, Assoc. M. Am. Soc. C. E., were made on February 20th and 21st, 1907, the temperature ranging from 18 to 35° fahr. The results of these tests, as given herein, are averages of from four to six operations, and show the indicated horse-power determined by simultaneous readings of the volt meter and ammeter. The entire current passed through the ammeter before being divided for the two motors, so that this reading gives the indicated horse-power, whether one motor or both were used. As many readings as possible were taken during each operation, and the results of these readings were averaged. The readings were taken in swinging the bridge through an arc of 90°, from the instant of starting to the instant of stopping.

The following is the time required:

Acceleration	20 sec.
Uniform movement	40 "
Retardation	15 "

The acceleration took place almost uniformly in an arc of 10°; the uniform motion was through an arc of almost 70°; the retardation took place in from 5 to 10 degrees.

The average indicated horse-power required to swing the bridge, open and closed, was:

During acceleration	44.9
During uniform motion	35.6

The retardation was accomplished by shutting off the current and applying the brake.

As the efficiency of the type of motor used is about 85%, the average effective horse-power for swinging the bridge was:

During acceleration	38.17
During uniform motion	30.3

MARTIN GAY, M. AM. SOC. C. E. (by letter).—In the hope of contributing something useful on the subject of Mr. Schneider's very valuable paper, the writer feels moved to offer some observations from the point of view of an engineer who has been charged with maintaining, for some years, a number of heavy swing bridges. Mr. Gay.

He has been particularly impressed by the fact that economy in first cost adds greatly to the expense of maintenance—economy, not only in workmanship but in material—and he ventures to submit that, however praiseworthy efforts in that direction may be, and however great the pleasure an engineer may take in the nice proportioning of the members of a structure to their work, such efforts are misplaced in the design of a moving bridge. The more rigid and unyielding the base, as well as the moving parts, of a turn-table, the easier and cheaper will be its maintenance.

The proper preparation of the top of the pivot pier under the track is not an expensive matter. It can be bush-hammered to such a level surface that the bed-plates will have practically perfect contact with the stone. The bed-plates should be planed on top and bottom to parallel surfaces, and both surfaces of the wheel treads should be machined accurately.

A heavy cover-plate on the lower flange of the drum, breaking joint with the flange angles and with the segments of the upper wheel tread, while offering some difficulties in construction, will add very much to the stiffness of the tread.

It is a very common practice to make up the joints in the base of a turn-table with shims, red lead, or some kind of cement, which will eventually work out. This should not be tolerated, as the necessity for it is evidence of bad workmanship which a proper shop inspection would have detected. The members should fit accurately, metal on stone and metal on metal, without the interposition of any filling.

As it is not in the skill of man to make an absolutely perfect machine, it is probable that no rim-bearing bridge has been built in which every wheel carries its full share of the load at all times, and it happens frequently that several wheels together carry no load. Therefore the drum should be very stiff. Of course, it will be as high as conditions permit, and it may be advisable to space the web stiffeners much closer than is usual in fixed plate girders. The drum should also be thoroughly braced against deformation, by struts radiating from the pivot.

Embedding the center casting in concrete does certainly interfere with its moving on its base, but, as Mr. Schneider remarks, "it does not prevent the pushing, pulling and wearing around the collar of the pivot," nor does it prevent the overturning of the casting, if the drum has a tendency to eccentric movement.

Mr. Gay. Of course, the center casting should be secured in place by bolts, concrete or any other means available, but the best insurance against its movement, and the eccentric motion of the bridge, with attendant damage to the turn-table, is a substantial, well-designed live-ring system, of the best workmanship. It should be built on the lines indicated in the paper, and should be so well braced and rigid, that, if a wheel or series of wheels, through maladjustment or accident, tends to roll out of the true orbit, it will not be able to deform the ring, or leave its proper position on the track.

One of the most frequent, annoying, and sometimes expensive repairs is made necessary by the inadequate fastening of the pinion bracket to the drum. The bracket itself should be more massive than may appear necessary to the draftsman at his table, and, in the opinion of the writer, should be built up of structural shapes rather than cast from iron or steel. It should be strongly fastened, by rivets if possible, and further secured by long horizontal brackets attached to the lower flange of the drum. The pillow-blocks and caps should be fastened with steel bolts, turned to a driving fit, in reamed holes. These remarks on the inadequate fastening of pinion brackets apply to center-bearing bridges also, the writer having had trouble of this nature with one recently built.

It is with diffidence that the writer ventures to disagree with Mr. Schneider even on the comparatively unimportant matter of shaft couplings. The arguments in favor of loose couplings are sound, and yet, on a number of bridges of varying lengths and construction, up to a pin-connected span of 400 ft., no trouble has been experienced with rigid flanged couplings; whereas, with claw couplings, there is some lost motion, there is usually a disagreeable chatter, and they have been known to fail. In fact, the writer usually keeps on hand a few flanged couplings with which to replace the claw couplings when necessary.

Another matter, quite unimportant, until viewed as a very frequent item of repairs, is the securing of gears, couplings and collars to the shafting with keys and set-screws. What virtue there is in placing keys and set-screws at an angle of 120° with each other is not apparent, but, if there is any advantage in that position, it should be known, and will undoubtedly be adopted; but, until the superiority of 120° over 90° is made clear, it is probable that engineers will adhere to the old, well-established practice, sanctioned by experience.

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PAPERS AND DISCUSSIONS.

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UNIFORMITY OF REQUIREMENT AND CLEARNESS OF SPECIFICATION IN AGREEMENTS FOR THE GRADUATION OF RAILROADS.

Discussion.*

By Messrs. F. Lavis, T. Kennard Thomson, E. H. Beckler, Harold Bouton and Samuel Tobias Wagner.

Mr. Lavis.

F. Lavis, M. Am. Soc. C. E.—The importance and timeliness of this paper, and the necessity of such uniformity in specifications and contracts as is possible under the varying conditions met in this class of work, can hardly be over-estimated, in view of the large interests involved, and the very divergent opinions held by engineers; to say nothing of the ignorance often displayed, not only by young engineers, who, working for salaries of $90 and $100 per month, have the responsibility of deciding questions of classification involving many thousands of dollars, but also by those higher up, who blindly copy specifications and contracts, no matter by whom they were written or what conditions were originally intended to be covered, and containing provisions which have been the cause of endless trouble both in and out of the courts.

The speaker is obliged to differ from the author, however, as to his final conclusion that a contract providing for classification, which is properly written, would be productive of better results than one under which a straight price is bid for all material excavated. Under this latter condition, however, there would possibly be cases

* Continued from March, 1907, *Proceedings*.

Mr. Lavis. where it might be advantageous to ask for separate bids on different sections of a long line where conditions might vary so much as to seem to warrant it, and also, of course, a separate price for foundation excavation both above and below water.

The author admits that under present conditions, the no-classification principle is rapidly coming into favor, but claims that in such cases engineers do not furnish sufficient information on which bids can be properly based. The argument, therefore, lies between the two alternatives: Whether it is better for the railroads to furnish the contractor with full, reliable information in regard to the work, and do away with classification, or, whether an attempt should be made to frame a specification which will eliminate all disputes. In view of the fact that even engineers are not always infallible, and that a decision as to classification has generally to be made on the spot by young and oftentimes inexperienced engineers, and also that, as a sound engineering proposition, proper information should be furnished to the contractor, there is little doubt in the speaker's mind that the former is preferable.

The necessity of providing full and accurate information to prospective bidders on new construction has been pointed out and emphasized by the speaker in a paper* read before this Society, and amplified further in his book: "Railroad Location, Surveys and Estimates." One of the necessary results of a location survey is therein stated to be:

"To have on the completion of the survey complete right-of-way maps, estimates of quantities, and costs, showing in detail the exact nature of the work, so that contractors can bid intelligently and work be started at once."

The value of an accurate map showing the accessibility of the work, its relation to the surrounding country and lines of communication, roads, trails, etc., on a convenient scale for use by the contractor in looking over the situation on the ground, was also pointed out.

This information is of just as much, if not more, importance to the railroad company as to the contractor, and, undoubtedly, should be obtained in all cases. On important construction, such as, for instance, the New York Subway, or the work which the New York Board of Water Supply has on hand, there is no question as to the propriety of spending all the money necesary to obtain as accurate information of sub-surface conditions as the state of the art warrants. The speaker does not for a moment advocate diamond drill borings to determine beforehand the nature of the material in an ordinary proposed cutting on a new railroad, but he believes

*"Methods of Location on the Choctaw, Oklahoma and Gulf Railroad," *Transactions*, Am. Soc. C. E., Vol. LIV, p. 115.

Mr. Lavis.

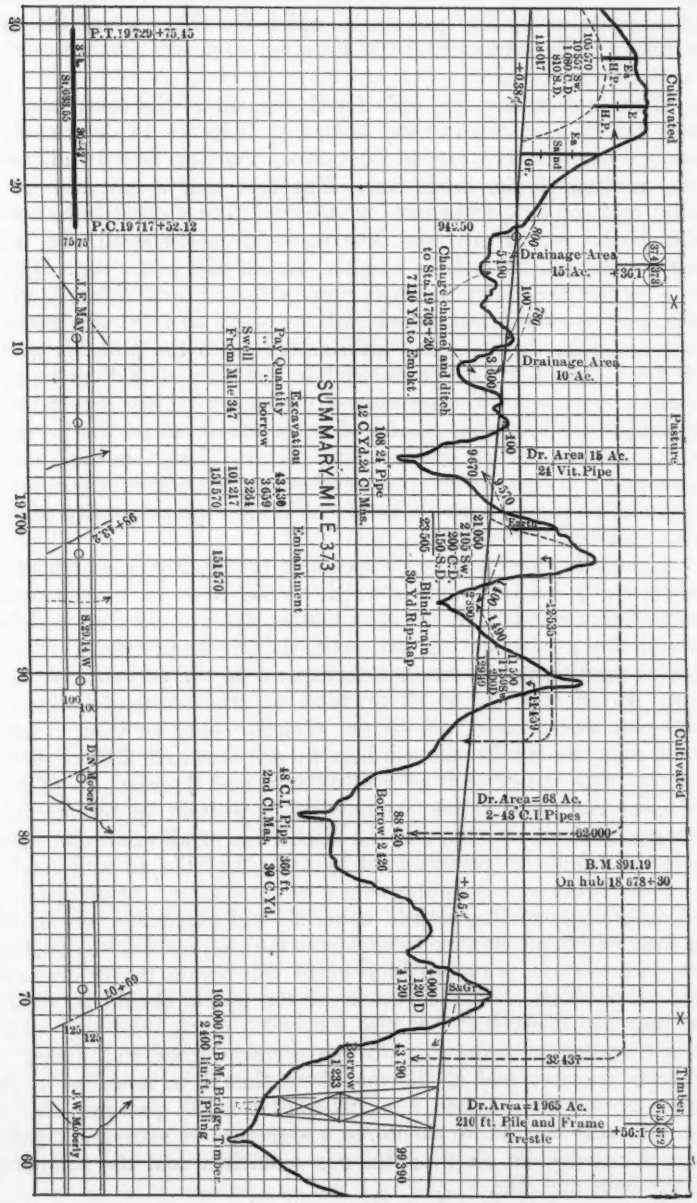


FIG. 1.

Mr. Lavis. that sufficient information should be obtained by auger borings or test-pits, or by any process by which the character of the excavation may be estimated with sufficient accuracy for the purpose in hand.

This is necessary, not only for the benefit of the contractor, but also for that of the railroad company, in order to determine, in many instances, the proper location of the line and, in all cases, the position of the grade line. The fact that a cut may be all solid rock, or 50% solid rock, or all earth, has a great influence on this latter, as, in one case, the material might swell and make more embankment and, in another, shrink and make less. Therefore, before the location can be finally settled, and before a grade line can be established, which will give the best balance between cuts and fills, the necessary information as to the probable nature of the material to be encountered in the cuts should be unquestionably obtained. The speaker is inclined to think that railroad managers are becoming more and more convinced of the necessity of doing this, and that there is more promise along this line than in attempting a revision of the classification specifications in order to put them on an equitable basis and beyond the possibility of misunderstanding and dispute.

The speaker has prepared a specimen profile, Fig. 1, which shows substantially the information which should be given to contractors on new construction or, for that matter, on any class of work involving the graduation of railroads, though modifications to suit special conditions will suggest themselves to the experienced engineer. In all cuts and at all foundations, the results of borings or tests-pits, where taken, are shown, samples being on view at some point near the work; the yardage in all cuts and fills is shown, together with the amount of swell if any; and the amounts of both side and cut ditches; the amounts of excavation in foundations; changes of channels, etc., and the disposition of all excavated material; the length of average haul by scale, and the amount hauled, the latter being especially important, as noted later. At all openings schedules of quantities, both of materials and excavation, are shown. In cases of important structures, where the character of the foundation is uncertain, a well-drilling outfit will obtain the information at moderate cost. At the bottom of the profile should be shown, not only the alignment, but also the width of right of way which it is proposed to acquire, with the division lines and names of property owners; and at the top, there should be notes as to the character of the country, *i. e.*, whether wooded, pasture, etc., as the case may be. There should be a summary of excavation quantities for each mile, showing the pay quantities and the balancing of the cuts and fills.

Mr. Lavis.

This information, together with a map of the line on a scale of 5 000 ft. to 1 in., as shown in Plate XII* of the speaker's paper previously referred to, will give the contractor all the information necessary, so that when he goes over the ground he can note the whole situation properly and make an intelligent bid. The map, showing the general relation of the line to the surrounding country and lines of communication, is very useful and necessary for the proper location of sites for construction camps and for estimating the haul of structural materials, supplies, etc.

Of course, all this information is given for what it is worth, and it is believed that there should be no more difficulty in a railroad company protecting itself against any claims of a contractor that he was furnished with misleading information, than the Board of Water Supply, for instance, finds in protecting itself because a contractor might be misled as the result of a wrong interpretation of the information shown by the diamond drill borings. All information of this kind must necessarily be used with judgment, and there is no doubt that the present tendency is toward a freer interchange of ideas between engineers and contractors. No responsible contractor should think of trying to "hold up" a railroad company because he has misjudged the information furnished by the engineers; and, on the other hand, the engineer should provide as full and reliable information as possible, explaining just how it has been obtained, so that it can be appraised at its proper value. It is believed that under these conditions a desirable contractor would come nearer to an equitable bid on a no-classification basis, on account of his large experience in judging conditions, than he would be able to if he had to take into consideration the unknown factor of the untrained judgment of a number of young and inexperienced engineers.

It should be remembered that the man on whom the responsibility of making the decision falls is the resident engineer, a young man with a salary of $100 to $125 per month, in charge of 8 or 10 miles of work. The division engineer usually gets over the work once a week, often only once or twice a month, and, usually, decisions have to be made on the spot, from day to day; he, therefore, is seldom in a position to determine accurately the merits of the controversies which arise, and too often falls back on an indorsement of his subordinates on what are called "general principles," that they should be supported anyway, right or wrong.

The information on the profile showing the proposed distribution of material from the various cuttings in the embankments, the speaker regards as most important, both to the railroad company and to the contractor, and especially to the former. In no

Transactions, Am. Soc. C. E., Vol. LIV, p. 128.

Mr. Lavis. other way, than by actually making this distribution as carefully as circumstances will permit, can either the locating engineer or the railroad company arrive at a true estimate of the value of the location, or realize the practicability of the scheme of work. The cost of the work to the contractor, and this always means sooner or later to the company, is very often increased by impractical conditions of haul which might have been avoided had the distribution of quantities been thoroughly threshed out beforehand. For instance, where possible, a solitary, heavy, steam-shovel and car proposition should be avoided, in the midst of country which can be more economically handled by teams; or, if it cannot be avoided, it may be found that considerable improvement of line and grade may be obtained by introducing sufficient additional heavy work, on adjoining parts of the line, which can be handled by the same outfit, so that the total actual cost of the work, due to the fact that the cost of installing the shovel and its equipment is distributed over a larger amount of excavation, will be so low as to justify the improvement. Many other instances, among others, the necessity of making proper provision for borrow-pits, will suggest themselves, which show the practical utility of thoroughly working out this distribution, besides the obvious advantage to the contractor of being able to estimate at least with a fair degree of accuracy what haul he has to provide for, and thereby minimizing one of the most fruitful causes of dispute and dissatisfaction, and enabling him to lay out his work ahead properly.

The author's remarks on overhaul emphasize the speaker's contention for more and better work on the location. There is undoubtedly a general impression that the line as originally located is likely to be changed so much during construction as to be hardly recognizable by the time the road is built, and the various changes of line and grade have been made in a frantic endeavor to balance the cuts and fills, and through a belated realization of the fact that the location has not been thoroughly threshed out, and that there is a chance to save thousands of dollars here and there, provided the construction has not proceeded too far to prevent it.

No one realizes better than the speaker the absolute impossibility of locating a line so that no advantageous changes are possible; but it is unquestionably a fact that a proper location, based on full and accurate information, properly studied and worked out to its logical conclusion, would reduce the changes to a minimum; and he believes that improvement is to be looked for more in the line of a thorough threshing out of the problems to be encountered before the work is started than by an attempt to overcome the defects of this lack of preliminary investigation by endeavoring

to provide a means of paying for what may turn up after construction is started. Mr. Lavis.

The difficulty of writing such a specification may be judged from one case, namely, that in which Mr. Dennis proposes, as a test for earth, the ability to plow it with four horses or mules of a certain weight. The speaker believes this to be impractical of application, although he is aware that it is very frequently specified. He knew of an instance where a contractor kept a special team for this test. The horses were kept fat and sleek, but they could hardly pull an empty scraper; and, besides this, the man behind the plow may make a great difference. In any event, there are so many instances where earth merges imperceptibly into hardpan, or from any one classification into another, that either the engineer would have to make the contractor keep his team and plow busy all the time making tests, or fall back on his own judgment. Anyone who has been connected with the ordinary contractor's outfit on actual work knows how difficult it would probably be to get any kind of a test made, unless it was at the company's expense. As Mr. Dennis himself points out, under the heading of "extra work," the contractor would consider that this was work which he was compelled to do, but for which he received no compensation. Even supposing the cut were taken out by taking off the top stripping with plows and scrapers—and by no means can a contractor be expected to use this method if some other seems more feasible—there would still be the theoretical necessity of testing the whole surface of the harder material with the team of the standard weight and pulling capacity. In large cuttings, especially where the material is being handled with steam shovels, and in cases where the overlying material is found in pockets, there is an increasing tendency to use well-drillers to bore holes through both earth and rock, or even through hardpan alone, in some cases, and then to blast the whole together. Classification, under such a method, would be almost impossible, in any event very difficult, and there is continually a tendency to increase the size of the cuttings considered feasible, in order to get the required good alignment and low grade necessary to handle the ever-increasing traffic of the railroads.

On betterments of existing railroads there would seem to be a still better argument for no classification, as the nature of the country can be very readily ascertained by an examination of the cuttings on the existing roadbed; in fact the largest amount of work being done under the no-classification specification is of this class, and it is an argument in itself in favor of the fact that better results can be obtained on that basis, provided the contractor can obtain reliable information as to the nature of the work.

Mr. Lavis. In regard to the question of engineering expense in making such preliminary investigations as might be necessary in order to make a proper estimate of the cost of doing the work, it might be pointed out that in all probability this would amount to but little, if any, more than that necessary to keep track of the measurements defining the limits of the various classes of materials, provided this were done in such a manner as to avoid any chance of dispute.

There can be but little question as to the endorsement of the author's position in regard to the application of the prismoidal formula to the calculation of earthwork; the method of average end areas is undoubtedly as accurate as any measurements which are taken of the surface of the ground. It is usual on some roads to instruct resident engineers to take sufficient measurements so that the difference in the center heights of adjoining sections will be within certain limits, say not more than 3 or 4 ft. Using the prismoidal formula on earthwork is on a par with the practice, on one road, of giving the degree of curve down to hundredths of a second, on account of a fancied idea that the ground is being fitted better.

The author's remarks in regard to extra items included in prices for excavation are also to the point. The reputation of an engineer or railroad company for fairness, or even liberality, in dealing with contractors is an asset which should not be underestimated by any means, and no matter how the contract is drawn up, a contractor will think he is being imposed on if he is compelled to build a wagon road for which he is not paid, even though it may be to a certain extent for his own benefit.

The fact that contractors are often compelled to bid on work, and accept contracts, regardless of the form in which they are drawn up, in order to keep their business going, as noted by Mr. Dennis, is something which is beginning to be recognized by thoughtful engineers who have gotten away from the old-fashioned idea that their business is to try and "do up the contractor," and who recognize that the interests of both contractor and employer are becoming more and more identified with each other. With this idea in mind, the speaker believes that both parties to the contract should recognize the necessity of the fullest frankness with each other, the engineer providing as full and accurate information as is possible in regard to the work to be done, and the contractor recognizing the limitations of all such information as to sub-surface conditions.

The old-time railroad contractor, whose equipment is such as to permit him to take only a small section of work which he is able to look after personally, and who, himself, has generally risen

from the ranks, is giving way to the modern complicated business organization, often a corporation, in some cases owning seventy or eighty steam shovels, with all the necessary complement of equipment which that involves, and employing high-salaried civil, mechanical and electrical engineers on their staffs; and it is believed by the speaker that a no-classification specification, accompanied by the fullest information as to the work, would appeal to such organizations rather than one providing for classification. Mr. Lavis.

While differing from Mr. Dennis in this respect, however, the speaker feels that he is to be highly complimented on the very practical nature of his paper, and for the very fair and skillful manner in which he has presented the matter, both from the engineer's and contractor's standpoints. His plea, for a fair, clear contract and for a better mutual understanding between both parties, is entirely in line with the speaker's ideas on the subject.

T. KENNARD THOMSON, M. AM. SOC. C. E.—The question of classification has come up frequently in foundations in New York City, especially in caisson work. In nearly all the lower part of the city, quicksand is found, from near the surface to the hardpan, from 30 to 60 ft. below, and, where caissons have penetrated the hardpan, it has been found to vary from 2 to more than 30 ft. thick, and, in some places, it extends to the rock. In other places, sand, boulders, etc., varying from 1 ft. to 30 ft. in thickness, are found between the hardpan and the rock. Occasionally, the hardpan contains an almost solid mass of big boulders, and sometimes only small pebbles. The big boulders generally have to be blasted. In some places the hardpan can scarcely be removed by the pick, and, in others, it is so soft that it crumbles readily in the fingers. Mr. Thomson.

Architects in New York usually have "wash-borings" made. These are carried down to what is called on the plans "bed-rock or boulders," but which is, in reality, the top of the hardpan. In one case, a contractor looked at these plans and signed a contract agreeing to go to "bed-rock." Although he had to pass through from 5 to 12 ft. of hardpan, which the plans did not indicate, he went to "bed-rock," but lost $20 000 thereby.

Wash-borings generally indicate the top of the hardpan very accurately, but, as they are made for this class of work, they do not show its thickness, nor the elevation of rock, so that the only fair way to let a lump-sum contract is to specify a lump sum for excavation to the average elevation of the top of the hardpan, and specify that everything below that depth will be paid for at so much per cubic yard, which price should be increased, probably for each additional 5 ft. of depth.

In passing through the material above the hardpan, as much as 20 ft. vertical per day can be excavated, while below the top of

Mr. Thomson. the hardpan, generally the excavation will not be more than from 2 to 4 ft. per day, and in cases where there is much blasting, 6 in. is the limit for a day's work. The result is that the engineer can calculate very closely what it will cost to go to the top of the hardpan, as given by the wash-borings, and he can calculate the extra cost for each additional foot of depth; but, if he tries to distinguish between good hardpan and poor hardpan, or boulders, or the material often encountered in the hardpan or under it, he will get into trouble, for all these materials blend into each other and vary for every caisson on the work.

Hardpan has been described as a natural concrete, in fact the speaker once heard two engineers disputing as to whether a piece of very good hardpan was or was not Portland cement concrete. As has been said, poor hardpan is sometimes so soft that it cannot be picked up without breaking.

Mr. Beckler. E. H. BECKLER, M. AM. SOC. C. E. (by letter).—This paper bears upon a subject to which the writer has given much thought in recent years. One's opinion, while attempting to discuss some of these questions, is certain to be influenced greatly by the point of view, and one's ideas are also likely to be affected by the vision. Everything is green or blue, when seen through green or blue glasses. To the best of the writer's knowledge, the eye-glasses he is wearing while attempting to discuss some of the points at issue are perfectly colorless. The writer, however, has no thought of being anything but loyal to the profession which stands first in producing men who are able in character and attainments, and whose success is never built upon the miseries or misfortunes of others.

There are some conditions in agreements, and some requirements in specifications, which have become obsolete through age, changes in business relations, and by reason of the use of modern appliances and methods of doing work. Other drastic clauses, giving authority to the agents of one contracting party, are inoperative, except in cases of financial embarrassment, attempted wilful wrongdoing, or default; and their presence in the agreement injures no one who proceeds with the execution of the work in a spirit of fairness and uprightness. It is true that one's pride is sometimes touched, but the knowledge that sentiment is not business should bring relief. It is certain that the presence of objectionable features which will not stand the test of law can do no harm. The same conditions apply to sub-contractors, who are frequently men of less intelligence, with weaker views of integrity, than the principals; and it is quite likely that a principal, who objects to the stringent requirements binding him, feels, at times, quite thankful that somebody's forethought has placed restrictions which are benefits in disguise.

Mr. Beckler.

The nature of the business is such that the contractor's pecuniary interests are closely represented on the work. He is in daily contact with the agent of the railway company, and is ever ready to present his side of a situation. The young men representing the railway company are, perhaps, too much taken up with the engineering and structural work, and are too inexperienced to comprehend and realize the judicial functions of the position. The specifications are for the guidance of such men, and it is better that there be not too much looseness, for that may make trouble. It is expected that there will always be near at hand some engineer in charge, who knows what is fair between man and man, and to him the contractor will look, more than to the chief engineer. In these days, where there is an operating department, the near-at-hand duties of the chief engineer often prevent him from giving much personal attention to a new piece of construction, until he can ride over the work in a car. Men at a distance must be held in check.

It is quite desirable that there should be greater uniformity in the general requirements, as contractors go from one road to another, acquire habits, and draw comparisons. When they meet unusual requirements, they are apt to say that the railway company is close, or even go so far as to say that they are being robbed, because of some variation from a custom practiced elsewhere. There are especial features with nearly every piece of work, and these should be specifically mentioned, in order to give assurance that the contracting parties knew the conditions, and were prepared to meet the situation. This prevents distrust and, possibly, litigation.

Method of Letting.

Lump Sum.—This method is without unit prices, or classification. It is possible that the information concerning a small piece of work may be sufficiently accurate and complete to enable fair tenders to be made. It precludes all modifications in plans during construction.

Unclassified Unit Prices.—The information for this method of letting must be nearly as complete as in the case of the "lump-sum" method. The usual clause requiring the contractor, in making his bid, in this and the foregoing method, to certify that his knowledge is obtained through his own agencies, if effective, compels much expense in the examinations; if waived, it is a foundation for a law-suit. Changes of grade or alignment make changes in the material encountered, in the character of the work, in haul, and in other ways, so that change in compensation must be allowed. Generally, changes operate favorably to the railway company. They are made for its benefit, are generally a saving, and, naturally, are against the contractor—in loss of profit, if for no other reason.

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For a no-classification bid, the contractor's risk appears to be larger, and the price is correspondingly higher, though there is a chance to catch the unwary or irresponsible. The claim that it avoids disputes is not substantiated. The study of the character and attainments of the engineer in charge should be a large factor in preparing a tender on this plan.

Classified Unit Prices.—The writer agrees most heartily with the author in his preference for classification; he endorses his arguments and commends to the attention of all engineers the clearness with which this point is covered.

A talk at one time with an engineer brought out the idea that the classification covered a definite material, and bore no relation, which an engineer should recognize, to the schedule of prices. He claimed that it would be disastrous to class material by relative cost (when properly handled), where the description did not definitely apply. The usual specification refutes this argument by describing loose and solid rock, and then naming earth as "all other material of whatsoever nature," with no attempt at description.

It would seem best to divide all excavation material into three groups in order to average the range of cost, although sometimes the middle price may be omitted. There are certain kinds of material, such as loose and cemented gravel, hardpan, gumbo, and plastic clay, which cannot be excavated at the usual earth prices. The unfortunate contractor who encounters these materials, and asks the engineer for a suggestion for economical excavating, or a hint as to the probable classification, draws little comfort from the reply.

As the author has well said, it is not difficult to describe the material most easily reduced to the loading condition. There is not much trouble in determining rock as such, although the writer once classified a frozen sand bank as rock, much to his chagrin a few months later. More mature thoughts have, in his mind, justified the unintentional benevolence. The portion of a ledge or mass of rock which can be removed economically without blasting is trifling. The seamy disintegrated capping is more troublesome than the solid mass beneath, and it is better not to attempt to separate it in the classification.

The words, earth, loose rock and solid rock, in the classification, are misleading. They prevent many, and especially young engineers, from perceiving that classification is an attempt to fit prices to the character of the material as judged by its resistance to removal.

CLASSIFICATION.

First Class.—This should include material which, in its customary natural condition, can be plowed by a team of 4 horses, each

weighing 1 500 lb., with reasonable rapidity for economical handling by scrapers or shovels, but does not require the use of picks or bars. Mr. Beckler.

Second Class.—This should include earthy or mixed materials, those not susceptible to plowing under the foregoing test, and boulders, embedded in first-class material, between the sizes of ½ cu. ft. and 10 cu. ft. Plowing with more than 4 horses, the use of picks and bars, and other hand work, and drilling and blasting are assumed to be some of the methods of loosening this material.

Rock.—This class should include all rock in masses larger than 10 cu. ft., and gravel containing cementing material and requiring the methods used for loosening rock. Drilling and blasting are assumed to be requisite for loosening and fracturing rock economically.

The foregoing leaves the opportunity to introduce a "third class," which might be necessary in some localities, to make the scheme more flexible. The price, with competitive bids, will fix the question of soft and hard rock. Under such a specification, the young engineers in the field will know that rock is rock.

Measurements.

The difference in volume between "end-area" and "prismoidal-formula" methods is due to the two pyramids in the slopes when there is a difference in end heights. The end-area method treats the pyramid as a wedge. This difference in volume may be found as follows:

Let S = the ratio of the base to the height,
D = the difference in the end heights,
L = the length of the prism,
X = the correction = the end-area volume minus the prismoidal formula volume.

$$X = \frac{S\,D^2\,L}{6} = \text{volume for both sides for a level cross-section.}$$

Substituting the proper values for

$$S = 1\tfrac{1}{2} \text{ to } 1,\ 1 \text{ to } 1,\ \tfrac{1}{2} \text{ to } 1, \text{ and } \tfrac{1}{4} \text{ to } 1;$$

then $X = \frac{D^2\,L}{4}, \frac{D^2\,L}{6}, \frac{D^2\,L}{12}, \frac{D^2\,L}{24}$, respectively, for these slopes.

It is seen that this correction varies directly as the length and as the square of the difference in end height. It is zero for any height of embankment equal at the two ends, and reduces to a small quantity as the slopes become steep in rock excavations. In earth slopes, short prisms make the error small. The difference in volume between end-area and prismoidal formula, with 1½ to 1 slopes, for a 50-ft. prism, with 4 ft. difference in height, is 7.4 cu. yd. The

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error of one-tenth, in the cross-section height for an embankment, 6 ft. high and with a base of 20 ft., is 7.1 cu. yd. It is not likely that the slope stakes, on ordinary ground, are accurate to within one-tenth. The natural surface of the country is convex over the ridges and concave in the depressions. The contractors lose many times the prismoidal-formula correction in the convexity of excavations and the concavity of embankments. To be consistent in applying the prismoidal formula, the ground should be planed or leveled before cross-sectioning, and the rod should be read to hundredths. There are steep gulches where it is inconvenient or unnecessary to take frequent cross-sections. The formula can be applied, but the methods used for determining the middle area are inaccurate and tedious. It is better to use the end area, and apply the little formula, previously mentioned, for a correction to the volume. Since the error is all in the slope, it is only necessary to use the side heights. A volume table for D may be quickly prepared.

Some specifications call for the measurement of all work in excavation. It seems to be a better plan to measure the embankment, when it is built from side-borrow. Frequently, the pits are not measured up for months. They become filled with mud and water, and when the quantities determined by pit measurement differ materially from the cross-section quantities, the engineer tries it again. He is delayed in rendering his final estimate, by this borrow-pit figuring, at a time when the contractors are impatient, and he is needed for other work.

Overhaul.

The question of haul is one of the most important under consideration, whatever plan is used, as regards compensation for the work, lump sum, unclassified, or classified unit prices. The exhibit shown at the letting, on which the compensation is based, cannot be changed, in right of way, grade, alignment, diversion channels, sidings, road-crossings, and incidental construction outside of the roadbed, without affecting the question of haul and the contractor's profits. It costs to move material, although not always in direct ratio to the distance or volume. The character of a piece of work may be so changed as to require a change of appliances for transportation at points where the delivery of the proper outfit is worth the price of the work.

On a "pay-both-ways" proposition, some cuts aggregating more than 100 000 cu. yd. were to be deposited in embankment where the ground was unfit for borrow. The line was shifted laterally to skirt a sidehill. A borrow-pit was made in the place of the original location from which material was hauled to the fill, thereby cutting out one price.

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A contract was made for a line which had been located during dry, autumn weather. The free haul was 1 000 ft. The profile showed a wide right of way—secured for the purpose of side-borrow—at all places where hauls of considerable height were to be built. In the following spring most of the low places were filled with water, and remained so for months. The contractors were obliged to haul from the high places, at scraper prices, using cars for the work. The original estimates indicated 60% side-borrow; the final estimates gave 70% hauled. A protest to the engineer in charge brought a shrug of the shoulders, and it is doubtful if the matter ever came to the attention of the chief engineer by more than casual mention by the engineer in charge.

A contract without any haul price included a section of 4 miles with a cut at one end and a long fill. In sub-letting, this section was undertaken at a price greatly above the principal contractor's average price for the entire work. The chief engineer consented, afterward, to let the sub-contractor waste some 30 000 cu. yd., and then made up an estimate including both waste and borrow, thereby taking $2 000 from the principal contractors and more from the railway company. These things show that there is indifference or a failure to understand the railway company's obligation.

It is best to have a price for hauling all material based, preferably, on the cubic yard and 100-ft. distance. This should apply to all roadbed excavation (no free haul), and to all borrow hauled more than 200 ft. If the price for haul is sufficient, the minor changes incident to construction do not cause loss. In justice to the contractor, hauling should not apply to extra work, which is not in evidence at the letting, when the excavations are off the right of way and below grade.

The methods of calculating overhaul are quite varied. When center of mass is mentioned, there is always doubt in the writer's mind as to his understanding of what is meant. The lexicographers, in definitions of center of gravity, mass, figure, volume, magnitude, etc., have made some confusion. Some engineers have shown surprise when told that the point where they add up one-half the yardage in a cut is not the center of mass. The true center, being a product of a unit by a distance, is only the center of figure in regular solids. There is no occasion to determine the center of mass. Unless one wishes to go into calculus, it is sufficient to use the prisms extending from one cross-section to another as units. Consider these units to be hauled to some selected point, as the end of the cut; ascertain the point in the embankment to which the same volume will make the fill; determine the haul to each of the embankment cross-sections, until the above fixed point is reached. The sum of the cut haul and the fill haul gives the required over-

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haul quantity. By this means, interpolation to find how far a given unit in excavation will reach, in the embankment, is reduced to the one operation of determining the extreme limit of the haul. Some mass-diagram methods are inaccurate, and, practically, the above scheme is used for those which are correct, permitting the eye to assist and check the mind. Where a borrow is overtopped by an excavation, the overhaul should apply to the distance actually hauled, and, if the bank is built up in layers, the usual plan of placing the nearest cut in the nearest fill is unfair. A strip of ground is often bought for borrowing the entire length of a fill, but, in calculating overhaul, the engineer will put the cut in at one end and the borrow at the other.

Sub-Contractors.

If the stipulation prohibiting sub-contracting is to be enforced, the engineer must let his work in shorter pieces. There are no outfits in existence capable of handling some of the larger pieces of work. Prices would go soaring, if one contractor had to own all the outfit. If there are several principal contractors on the same line, there will be continual squabbles over labor, supplies, etc. With sub-contractors acting as foremen, there is better progress and workmanship, and more economical management. While it is not nice to sign an agreement not to sub-let, and immediately proceed to cover a line with foreign parties, it is possible that a modification of the stipulation which definitely states that sub-contractors may be employed, and that the principals will be expected to shoulder all the expenses, of whatsoever nature, that the often-misguided "subs" may choose to incur, may be like "jumping from the frying-pan into the fire." It is better to "let silence give consent."

Insurance.

Sometimes the clauses relating to the protection of the railway company are worded in a way to touch the sensibilities of a self-respecting man. Except for the fact that the work is more hazardous, there is no occasion for greater restrictions than in the purchase of material and equipment. On account of the hazard, it is doubtless best that the railway company insists that accounts shall be properly kept. The inspection of the books and pay-rolls, and the assumption of management of the contractor's forces, are not the company's business until there is evidence of incompetence and probable failure.

Delays.

Contractors are entitled to compensation for delays occasioned by the other party. Extension of time does not pay for feed and

idle labor. The claim for delays ought to be made promptly, and its merits determined immediately by a competent person. A tender was once made for a piece of work on which the contractor was to load cars to be hauled away by the railway company. The bidders proposed having a timekeeper, employed by the company, to record idle time after any 15 min. delay for cars, and payment was to be made for the time less the 15 min. The bid was rejected, because, as the chief engineer said, it left a chance for dispute. The object was to avoid dispute. The party who took the contract, without such provision, afterward told the writer that he had lost money because of the delays. Mr. Beckler.

The Chief Engineer as Umpire.

There is some probability of the chief engineer being biased in his opinions, on account of estimated cost and pressure by the management. There is greater probability of the contractor assuming this to be the case, because the engineer is an employee of the other party. This opinion is more likely to be the fact, as regards the subordinate engineers. It is quite likely that many chief engineers would like to have the duty of being umpire taken from them. It would be well to have every contract state that some engineer, not an employee of either party, shall be the umpire to decide all questions pertaining to changes made during the progress of the work, or to adjust all claims of contractors for extra compensation. The compensation for the service of umpire should be borne equally by the parties. The chief engineer is frequently prevented from making changes because of the uncertainty as to the feeling of the contractors, and, if it were known that an umpire was agreed upon to settle any question of compensation, the engineer would be less troubled in arranging for work introduced by unforeseen difficulties. It is best that much of the extra work not provided for in the contract at unit prices, or work not plainly indicated in the beginning, should be done at cost, with a percentage for the use of tools and superintendence. Such bills should not be juggled into yardage, especially when the work is done by a sub-contractor. His price is not that of the principal, and he is entitled to the full amount of his bill.

Some of the objectionable features of contracts, from the contractor's point of view, have been inserted by the attorneys directly in the employ of the railway company, who have been told to draw up something binding. The contractor is surely at fault for signing an agreement containing conditions which are humiliating, or which are too one-sided. Such matters can be made satisfactory before the papers are signed. It would be well to have the railway contract forms of agreement and specifications revised, like the

Mr. Beckler. American protective tariff, by its friends, that is, engineers and engineering contractors; and a committee of the American Society of Civil Engineers is the proper vehicle to use in making this needed reform.

Mr. Bouton. HAROLD BOUTON, ASSOC. AM. SOC. C. E. (by letter).—The scope of this interesting and important paper is too great for a thorough discussion by the writer. Many of the questions raised require a knowledge of the law of contracts as well as the facts. Many of the evils and defects of which the author complains, however, are only unfair, though a number are illegal; but whether unfair or illegal, they are expensive to the employer, as the author points out. As long as contractors must take contracts as they find them, and as long as competent parties are allowed to contract to do anything not illegal or against public policy, until then will contractors, who are alive to their interests, rely on ambiguous clauses and engineers' interpretations thereof to relieve them; and they will liquidate their damages by resort to a court, or insure against such damages by a high price, or both. Contractors who do not bid high under such conditions are, as Mr. Dennis says: "not the most reliable, but the most optimistic."

The writer is familiar with the subject, and, having considered it from several points of view, the causes of the defects in the present system, seem to resolve themselves into two general classes, which would seem to be confirmed by this paper:

1.—Insufficient or unreliable data for the inspection of bidders, and by which they are to be bound;
2.—Lack of definition and limitation of the province of the engineer in drafting the specification and the contract.

Economic reasons would seem to be sufficient to prompt every competent engineer to make the circumstances and conditions affecting each contract as certain as possible for the inspection of the bidder; at least, when these have been, or can be, made reasonably certain. Lack of time or funds is the excuse usually given, but the time devoted by the average engineer to drafting the contract in supposed legal form will generally refute this, and the same time spent in intelligent investigation and collection of data would render unnecessary the usual attempt to shift the responsibility for not having done so; and the first cost of precision will bear favorable comparison with the final cost of uncertainty.

As Mr. Dennis says, general clauses are a confession of weakness. Precise, clear statements need no definition or protection. Ambiguous and uncertain clauses, inserted to avoid the legal consequences of uncertainty or worse, need definition, and usually get it, at the expense of the employer.

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There is a reason for the insertion of these clauses which, unfortunately, often controls. It arises from a desire to confirm a preliminary estimate of the project, made on a superficial survey of the location, facts and circumstances, and on the basis of the "average price of similar work," at a time when the authorization for the work depends on the estimate.

Improvement can hardly be expected until the fundamental differences and essentials of cost and price are more generally recognized and satisfied.

Limitation of the province of the engineer is perhaps the most important topic of discussion suggested by this paper, particularly because of its very declared purpose and its title.

Of all defects in the present system, the usual method of drafting contracts and specifications is the most glaring and the most productive of litigation. With insufficient or withheld data as a foundation, a scrap-book structure is erected from other specifications and contracts, themselves seldom original, which have been drawn to satisfy work of a different character, or at least affected by radically different circumstances and conditions, and in another section of the country; and great effort is made to satisfy legal as well as engineering requirements.

This fault, no doubt, arises mainly from the fact that the technical knowledge necessary to draft a contract and specification is usually beyond the province of the lawyer, as it varies with and in each contract; but the fundamental essentials of the law of contracts, necessary to make it binding upon the parties thereto, are generally constant. The error results from not segregating the matters of fact from those of the law. The engineer and employer should agree on the facts, and separate the technical from the general. The technical will vary with each contract. The general facts will be more constant, but will also vary to some extent. It is feasible, however, to compile a schedule of general facts incidental to the average engineering contract and place it in the possession of every engineer, so that a choice of these may be made for each new contract, with the addition of any other facts which the circumstances may suggest. When selected by engineer and employer, they should be referred to one who is qualified to draft them in legal form; but to go further than to standardize the facts of general clauses would be a grave mistake.

There remains that portion of the contract which engineers should not try to draft, and that is the purely legal part wherein is recited and defined the parties, general subject matter, and consideration. The effect of a standard form of agreement, even if this were made with legal assistance, would be disastrous, for

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many would assume its infallibility. Such a standard form would not satisfy even all railroad contracts, and if insertions or other changes were made by a person not conversant with the fundamental essentials of a contract, the result would be very dangerous and unfortunate. A knowledge of the law of contracts is a desirable qualification in every engineer; not for the purpose of drafting contracts, but that he may understand the importance of clear, concise and exact terms, and avoid the use of clauses so general as to seem to be designed to permit the engineer to avoid any consequence of his own neglect or error.

The interest and discussion, when these questions arise, show that the study of legal principles is taking the place it should in an engineering education. It seems ridiculous to attempt the legal without a knowledge of the successive relations in a contract, namely: Formation, Operation, Interpretation, and Discharge. Further, there is no contract unless the following five essentials of Formation are present and are satisfied:

1.—Offer and Acceptance.
2.—Form and Consideration.
3.—Capacity of Parties.
4.—Reality of Consent (Mutuality).
5.—Legality of Object.

An admirable discussion of these questions may be found in the paper* by Albert J. Himes, M. Am. Soc. C. E., but a brief reference to each of the contract relations may be excused because of their extreme importance.

Formation.—This corresponds to the Proposition and Execution of the contract, and is written evidence of the limits to the rights and obligations of the parties. Its successive requirements are:

I.—That the acceptance must be in the precise terms of the offer, and unconditional;
II.—That written form is necessary, and the consideration real, though not necessarily adequate;
III.—That the parties must be not only legally and mentally capable, but acting within their authority, if representatives;
IV.—That, for mutuality, the minds of the parties must have really met on the same subject-matter;
V.—That while legality may seem self-evident, regulations or ordinances, charters, statutory and other law, unknown and unsuspected by an engineer, may result in the illegality of the contract.

* *Transactions*, Am. Soc. C. E., Vol. LVI, p. 104.

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Operation.—Operation, corresponding to Performance, tests the limits of the rights, liabilities and relations of the parties and of the subject-matter; including the very important ones of sub-contracting, sureties and bankruptcy.

Interpretation.—Interpretation means definition, and is regulated by the intent of the parties, as shown by the written instrument and the surrounding circumstances; but, while parol evidence may explain, it cannot vary or modify the written terms.

Discharge.—Discharge or Termination may take place by waiver, substituted agreement, substantial performance, breach, impossibility of performance, and by operation of law.

The important question of classification, to which the author devotes much of his paper, deserves consideration.

The classifications, "Earth," "Loose or Soft Rock," "Solid or Hard Rock," as the author says, seem to be founded on a desire to isolate in each of these classes those materials for which the unit cost of handling is approximately the same. The author then proceeds to make his suggested improvements on a similar basis, though the paper, in its analysis, shows that while the factors of cost and price include that consideration, others are quite as important if not controlling. There seems to be another reason for the present system of classification. It is that of uncertainty and a desire to limit to some class, materials for which the engineer feels unable to estimate the cost; for example, "quicksand," in the "Earth" class.

Believing that the system is fundamentally wrong, the writer cannot agree that the author's suggestions are an improvement. Also, it does not appear to him that the suggestions for determining the class will work satisfactorily in practice, or lessen the usual friction and differences of opinion. The author's suggested classification is, indeed, on a basis of loading condition, and approaches closely the true economic relation; but his method of ascertaining this condition would seem to accomplish nothing more than could be done by tests more scientific in principle and quite as practicable. Teams and plows do not seem to be in accord with the present rigid tests for many materials. "Horse power" is no longer recognized as a measure of the working force of an average horse; and how much less will "two men working to keep one man busy" measure a constant standard of work, when so much depends on their strength, temperament, inclination and other characteristics? Nor is there any accurate measure of the power of explosives to overcome the resistance of materials. Should there not be as fair and exact tests and definitions of materials for destruction furnished by the employer, as of materials required of the contractor for construction? Any improvement should provide

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more definite information for the bidder, lessen the ambiguity as to what price will be paid, and thereby lower the price.

The present system of postponing quality as well as quantity of all excavation materials, until after the execution of the contract, induces honest differences of opinion which tend to weaken the mutuality; and it is because Mr. Dennis proposes to continue what seems to be a fundamental defect, that the writer disapproves of his recommendations, even if his criteria are practicable.

A responsible contractor, whatever the classification specified, endeavors to determine exactly the quality, quantity, location and disposition of the material, and then, according to his resources, experience, and the specified and other conditions, he will add to his estimated cost an amount which he hopes will include a profit. He looks for cause first and at effect next; but the engineer asks for bids on effect first, and ascertains and defines cause later. The contractor's time to investigate is usually short, and if the data provided by the engineer are insufficient or unreliable, and his own examination is unsatisfactory, the uncertainty is paid for in the price. The price of the usual class is not even an average of quality, though the materials are reasonably ascertained, for the party who pays does not determine their quality at the time the contract is executed; and, instead of paying a definite price for definite materials, the employer more often pays a price safe to bid, on what may prove to be a group of unlike materials, the quality and quantity of which the engineer will ascertain and determine after the price is made.

Rock formations, for which the usual classification strives to produce a lower price, might be said to be confined to very definite kinds of deposits, generally speaking, stratified rock and those which are imperfect because they are in process of formation or disintegration. The railroad classification clauses quoted by the author refer—by name and character of deposit—to well-known materials, as criteria of the very quality they attempt otherwise to define in the same clause, and thus show the futility of trying to classify quality. If a material is named, its quality is at once apparent to a person of average intelligence.

Geology provides a classification that is standard throughout the world and satisfies every requirement of practicability, exactness and inflexibility. The names given to individual rocks and deposits of Nature are so invariable that their physical, if not their chemical and mineralogical, characteristics are known to most parties likely to be interested, and further information regarding them can be readily obtained.

With this as a natural, scientific and established basis, and also the very one by which the contractor consciously or unconsciously determines costs, the writer, without assuming to tabulate all the

materials that should be found in each class, proposes the following scheme of classification: Mr. Bouton.

Soil.—Soil shall be rock or like material, the particles of which are not cemented together, but are in a granulated or powdered condition when dry; and shall include material, wet or dry, as found in its natural state. The various soils shall include sand, earth, clay, gravel, muck, gumbo, quicksand, and others that satisfy the definition in this clause.

Indeterminate.—Materials in the indeterminate class shall be rock, or like material in process of formation or deterioration, the constituent particles of which are sufficiently cemented together to support their own weight without breaking or cracking either when dry or wet; also, rock of any kind found in masses exceeding 1 cu. ft., but not exceeding ½ cu. yd., in volume, as a result of fracture or any other natural cause. The materials in this class shall include indurated clay, cemented gravel, hardpan, weathered, decayed or otherwise deteriorated rock, boulders or fractured rock not exceeding ½ cu. yd. in volume, and others satisfying the definition in this clause.

Rock.—Rock shall be mineral masses composed of materials, the particles of which are in a state of perfect cohesion, as usually determined geologically for its kind, and not yet deteriorated to any appreciable depth from any given natural exposed face. They shall be classified generally as follows, for masses exceeding ½ cu. yd. in volume:

I.—Of physical character similar to that of deposits known geologically as aqueous, including shale, slate, sandstone, limestone, etc.

II.—Of physical character similar to that of deposits known geologically as metamorphic and igneous, including trap, granite, gneiss, syenite, marble, mica-schist, and some sandstone, etc.

Extraordinary.—Extraordinary shall be special work of any character to be defined as occasion arises, before letting the contract if possible, and paid for on a basis regulated by the circumstances. For example:

Foundation.—The foundation shall be of a character preliminary and consequent to the placing and location of permanent work and materials below or above the average water level of the site, and shall include all false-work, materials, labor, and the use of plant and appurtenances that the contractor deems necessary, provides and uses, for successfully completing and maintaining the conditions of preparation and location of permanent work built and left as finished at the particular site in question. Foundations shall be classified as:

(*a*) Dry—Above water level;

(*b*) Wet—Below water level.

Mr. Bouton. On this basis, a schedule should be formed from the country rocks and soils expected or likely to be found at the location. If the rocks and soils are of unusual character, the schedule should include a reference to materials usually found elsewhere, as a basis of comparison. Under the general heads just given, each material should be mentioned by name in its proper place, and a bid should be asked for each separate item scheduled. For each or any material which may be found in course of excavation, but which is not expected, or is of doubtful quality, it should be specified that it shall be placed in one of the general classes and be paid for at the price bid for the material or rock which it most nearly resembles. It should be specified that disputes shall be settled by submitting standard samples to a third competent party for such classification, or, if necessary, by tests of the same general character as those now provided for natural and artificial rock, stone and materials used in construction as building stone, sand, cement, concrete, brick and the like. The standard tests might include and provide for a selection of the following for each material or rock: Heat, absorption, specific gravity, fracture, attrition, tension, compression, cohesion, adhesion, formation and other physical, chemical and mineralogical attributes.

The test of heat, absorption, compression and tension would be likely to remove any reasonable doubt as to whether any material—such as hardpan—should be classed as "Soil," "Intermediate," or "Rock."

It might be advantageous, in many instances, to use Class 1, Class 2, etc., or Class A, Class B, etc., as alternative headings for those given in the suggested classification herein; but, whenever the present general practice of classification is used, classification by numbers or by letters is far preferable to the terms "Earth," "Loose or Soft Rock," and "Solid or Hard Rock." The latter terms, almost invariably, designate a classification including materials distinctly different, and the continued use of such terms is certain to perpetuate the past and present difficulties of interpretation.

Rigidity is not suggested, and modification will be necessary in each particular instance; but the advantage of a certain, established, reasonable custom, in the rules of evidence, cannot be overestimated.

How far this or a similar classification may have been advocated, or adopted and rejected as impracticable, in the past, the writer is unaware, but will be pleased to learn.

Mr. Wagner. SAMUEL TOBIAS WAGNER, M. AM. SOC. C. E. (by letter).—The writer is decidedly in favor of an unclassified price for excavation, under most conditions of a general character, and more par-

ticularly where municipal work is concerned, or where a municipality is interested in the contract. Where such price is unclassified, he considers that the contractor is entitled to all the data which can reasonably be obtained by the engineer. General plans showing the roads, railroads, and means of access to the work, and profiles showing the cuts and fills, and the approximate distribution of the material, should be given. Water-jet borings should also be made at reasonable intervals. While borings of this class, as a rule, are very unsatisfactory for showing the character of the rock formation, they can be used to show a reasonable line of demarcation between earth and rock, and thus furnish a basis by which the contractor, in making up his bid, can determine the relative proportions of each. Mr. Wagner.

The writer has in mind a large piece of municipal work executed under his charge, involving about 1 000 000 cu. yd. of excavation, on which an unclassified price was used, and on which frequent water-jet borings were made. As the work progressed, the borings were found to show, almost invariably, the approximate line of the rock, and the contractor was able to make a price which was equitable to both parties.

The compilation of the practice on different railroads, made by the author, is interesting and startling in the differences shown in the specifications for the classification. On the road with which the writer is connected (The Philadelphia and Reading Railway), the practice varies. When classified, the following specification is used:

"Excavations shall be classified under the following heads: Solid Rock, Loose Rock, Earth, and Excavations in Water.

"Solid rock shall include all rock found in ledges and in detached masses, exceeding 1 cu. yd. each, which, in the judgment of the Chief Engineer, may best be removed by blasting.

"Loose rock shall include all kinds of shale, soapstone and other rock which can be removed by pick and bar, and is soft and loose enough to be removed without blasting, although blasting may occasionally be resorted to: also detached stones of less than 1 cu. yd. and more than 1 cu. ft.

"Earth shall include all materials of an earthy nature, of whatever name and character, not unquestionable rock, as above defined.

"Excavations in water shall apply to foundation pits under water, and deepening of channels in running water: it shall include drainage, bailing, pumping and all materials and labor connected with such excavations: also the necessary dressing of rock for the base course of masonry. The materials removed from excavations in water shall be classified and determined in the same manner as materials removed from other classes of excavations, *viz.*, as solid rock, loose rock and earth."

Mr. Wagner. The writer fears that the classification proposed by the author will be very difficult to apply practically, and will not simplify the question.

One trouble with classified work is the difficulty in verifying the actual conditions if a dispute arises after the work is done. This calls attention to the necessity of the engineer and contractor taking up and settling on the ground from day to day such questions, and not waiting until the progress of the work has obliterated all traces of the actual conditions.

It is a great mistake to include, in any price bid by the contractor, anything more than the actual items which are distinctly appurtenant thereto, unless the specifications can indicate precisely what is to be included. Even then, in most cases, it is better to have in the proposal special items for the extra work. Nothing is more unfair than to ask a contractor to do something which cannot be distinctly shown on the drawings or specified in advance.

The writer does not believe in extra work—that is, force-account work—where it can be avoided, but in some cases it is the only fair method to be pursued. In such cases it would seem to be wise to have, in the proposal, prices agreed upon to be paid for the several classes of labor, and if the quantities are checked daily by the engineer and contractor it is certainly an equitable method of procedure, and open to no serious objection. In such cases it should be understood that such prices include a necessary percentage for the use of ordinary tools, cost of superintendence, and profit.

The writer thoroughly agrees with the author that nothing should be asked in a specification which is not practicable in the work. Such clauses should be omitted by all means. Many clauses of this kind creep into specifications because they have been in previous ones, and their presence is due to the shears and paste pot more than to anything else.

It is unfortunate that much work has to be put under contract without the preparation of thoroughly digested plans and detailed specifications, but conditions often require such work to be done. Often, too, the right of way in certain localities cannot be obtained before the work is put under contract. In such cases, the responsibility of the engineer, in determining the equity between his employer and the contractor, is very great. There are few engineers who would not rather wait until these points are cleared up before asking for bids, but too often the conditions will not allow it.

Some specifications require the contractor to be responsible for any damage which may occur to property, etc., during the progress of the work. This clause has interested the writer for

Mr. Wagner.

many years. His experience has been that, no matter how the contract be worded, so as to make the contractor responsible, the courts will not hold him so if it can be shown that he has carried on his work in the usual manner in which such work is carried on by a good and successful contractor. It is necessary to prove negligence in order to hold him, and such proof is not easy. The writer is of the opinion, therefore, that it is better to omit such clauses, direct the contractor how to proceed in detail in cases requiring care, and take the responsibility, than to retain the clause and have the contractor add a contingent item when making his bid in order to cover imaginary cases which may never occur.

The author is to be congratulated on the preparation of a paper so rich in problems which are of frequent occurrence, and it is to be hoped that the discussion will be fruitful in clearing up many points upon which an improvement can undoubtedly be made.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

CHARLES HUMPHREYS, M. Am. Soc. C. E.*

DIED NOVEMBER 18TH, 1906.

Charles Humphreys was born on May 2d, 1853, in Lowell, Massachusetts, where his father, Joshua, though still in the Navy of the United States, but on leave of absence, was in charge of the Middlesex Mills of that town. His mother was Miss Margaret Chandler, of Georgetown, D. C. His father entered the United States Navy as a Midshipman in 1829, being third in his class. In the War with Mexico he served with credit in the fleet before Vera Cruz, and did other valuable duty, on surveys, etc. He resigned from the Navy in 1853, and was engaged in civil pursuits until the War between the States began. He then entered the service of the Southern Confederacy. Joshua Humphreys died in Fredericksburg, Virginia, in November, 1873, at the age of sixty.

The ancestors of Mr. Charles Humphreys came from Wales as early as 1682 and settled at Haverford, Clinton County, now Delaware County, Pennsylvania, near Philadelphia. His great grandfather, Joshua, was in the military service at the battle of Trenton, and thereafter until the close of the War of the Revolution. He was a member of the Philosophical Society of Philadelphia. This Joshua was one of a group of famous builders of that period; and, in 1792, when the navy had become a matter of general interest, he ventured to send letters, giving his views of the needs of the situation, to Robert Morris and to General Knox, then Secretary of War and Navy. In these suggestions are already to be discerned the principal elements in American success in ship building—originality and adaptation to our own circumstances. Humphreys claimed that as the number of our vessels would necessarily be inferior to that of the European navies, ours must be light enough and fast-sailing enough either to decline a battle or accept it at will; and yet, if our vessels should enter a battle, they must be equal in fighting abilities, vessel for vessel, to any vessel of any size. He proposed, therefore, to make the vessels larger and longer, and yet lower, than the existing type. The same number of guns could then be placed on one deck as had previously been placed on two, and, either in heavy winds or in light, they could outsail existing European ships, could easily overcome those of the same rate,

* Memoir prepared by William P. Craighill, Past-President, Am. Soc. C. E.

and meet on equal terms those of a higher rate. His suggestions were accepted, and when Congress ordered the building of six ships of war, Humphreys was instructed to prepare the models for them. He did so, and the six vessels, *Chesapeake, Constellation, Constitution, President, Congress,* and *United States,* were built at various places on his model, the last in his own shipyard at Southwark, Philadelphia. The ship-of-the-line, *Philadelphia,* launched in 1799, was also built by Humphreys at his own yard. The work done by these vessels fully justified the ideas of their builder. Their model exerted a very great influence, not only on our own subsequent navy, but on that of England and other countries as well.

Charles, the brother of Joshua, was an active and influential member of the Continental Congress from 1774 to 1776.

Samuel Humphreys, the son of Joshua, was brought up in the shipyard, taking charge of the business in 1808, being appointed constructor for the Philadelphia Navy Yard in 1813, and Chief Naval Constructor of the United States in 1826, a position which he held until his death, in 1846, in Georgetown, D. C. He was the builder of the steam frigate, *Mississippi,* Perry's flagship in the Mexican War and in his expedition to Japan. Great pecuniary and other inducements were offered to him to enter the service of Russia, but he preferred to devote his time and talents to his native land.

Major General Andrew A. Humphreys, uncle of the subject of this sketch, after being graduated at West Point, served in the Indian War in Florida, and won great distinction as a member of the Corps of Topographical Engineers of the United States Army, especially for his studies and writings on the "Hydraulics of the Mississippi River," and the surveys for the locations of the transcontinental railways. In the War between the States he was gallant and prominent as Chief of Staff and as a Corps Commander in the Army of the Potomac. After that War he became Chief of the Corps of Engineers of the Army.

The career of Charles Humphreys was cut short by death in Washington, D. C., on November 18th, 1906. His health had failed for several years. His disease was incurable by medicine, and an operation would have been fatal. His last illness was tedious, but he was comforted by the devoted attentions of his wife and children, and bore his suffering with the fortitude of a brave man and the patience and resignation of a sincere Christian.

He entered the service of the United States at the age of seventeen, in a subordinate position, and did not have the advantage of a technical, collegiate education; but his natural ability, his strict and faithful attention to every detail of duty, with thorough study of every subject in the profession which came under his

care, and a wide and varied experience, made him one of the most capable, trusted and successful civil engineers. He was engaged for thirty-seven years upon the improvement of rivers and harbors and the construction of the fortifications of the country. As a surveyor and draftsman, he was specially expert and careful. He inspected the quarrying, cutting and erection of the beautiful Centennial Monument at Yorktown, Virginia. He was engaged for a number of years on the movable dams of the Great Kanawha and Ohio Rivers; on the improvement by jetties of the bar at the entrance of Winyaw Bay, South Carolina; on the improvement by dredging of the bar at the mouth of Cape Fear River, North Carolina; of the Patapsco River in Maryland; of the harbor of Norfolk, Virginia; and was connected with many other improvements of less importance.

He was held in the highest esteem by all his official superiors, by his comrades, and by those who served under him.

The following extract from a letter of an officer of the United States Corps of Engineers is but a sample of many that have been received:

"In all the relations of life in which I knew or observed him, in his family, among his associates, and in his official duties, he was a man of the most sterling character and qualities. As Assistant Engineer, he was thorough and efficient in the office, in the field, in important surveys, and upon works in the immediate direction and management of men.

"As an engineer, his observation was close and intelligent, and his judgment sound.

"He was utterly unsparing of himself, in his industry and application in the office, and in exposure of himself in the field. Such was his simplicity of character, modesty, and forgetfulness of self, that he was little adapted to obtaining, of himself, what his merits deserved.

"He was a vestryman and warden in a struggling church at Wilmington, North Carolina, and, in his simple, retiring way, was of excellent influence in his community.

"I lament his death, and shall ever bear him in affectionate remembrance."

The following short extracts are from a letter of an associate who knew him very intimately:

"Charley was a man clear through—one of the best kind—a practical, well-informed, affectionate fellow, with no frills, and one who could be relied upon to an unlimited extent. His sympathies were excited by anyone in the least distress, real or imaginary, and it came as natural to him to give comfort as it is for water to run; he could not help but do it. He learned his profession in a practical way while working in the field or at the drafting board, with books as his companions in both places. He

was very studious of technical books of the profession he loved, and was assisted in his progress by his aptness with mechanical tools, of which he purchased many and used them in making models of bridges and other engineering structures. In these models he delighted in demonstrating that the structures were symmetrical and the different parts nicely adjusted to the relative strains. In this thorough, practical way he learned his profession; and the way, in my opinion, illustrated the manliness of the man.

"Officially, Charley was unostentatious, but never undignified. His manner was plain and kind, but there was a something, indescribable but recognizable, about him that repelled all presuming upon it to take advantage of his good nature. I always thought him an ideal man and official—not brilliant or dashing, but faithful to the point of utter reliability in every direction."

Many other letters of similar tenor could be added, and the present writer, who knew Mr. Humphreys, as boy and man, for nearly forty years, can heartily concur in all that has been said by others, and wishes to add his own testimony to the purity and excellence of his character as a man, and his ability and unusual merit as an official.

Charles Humphreys married Miss Elizabeth C. Hungerford, a member of an old and prominent family of Maryland. He left three children, two daughters and a son, the last taking up the profession of his father, after being graduated at the Rensselaer Polytechnic Institute at Troy, New York.

Mr. Humphreys was elected a Member of the American Society of Civil Engineers on February 1st, 1905.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

(INSTITUTED 1852.)

VOL. XXXIII. No. 5.

MAY, 1907

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The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

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INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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MINUTES OF MEETINGS.

OF THE SOCIETY.

April 17th, 1907.—The meeting was called to order at 8.45 P. M.; Director A. L. Bowman in the chair; Chas. Warren Hunt, Secretary; and present, also, 184 members and 42 guests.

A paper by William B. Fuller and Sanford E. Thompson, Members, Am. Soc. C. E., entitled "The Laws of Proportioning Concrete," was presented by Mr. Thompson and illustrated with lantern slides. The paper was discussed by Messrs. J. L. Davis, H. de B. Parsons, Allen Hazen, William B. Fuller and Sanford E. Thompson.

The Secretary announced the following deaths:

CHARLES BLACKWELL, elected Member September 7th, 1881; died December 29th, 1906.

EUGENE GRIFFIN, elected Member June 7th, 1899, died April 12th, 1907.

FRANK LESLIE FREEMAN, elected Associate November 5th, 1895; died March 3d, 1907.

Adjourned.

May 1st, 1907.—The meeting was called to order at 8.40 P. M.; Director A. L. Bowman in the chair; Chas. Warren Hunt, Secretary; and present, also, 136 members and 25 guests.

The minutes of the meetings of March 20th and April 3d, 1907, were approved as printed in the *Proceedings* for April, 1907.

The Secretary presented the Reports of the Committees of the San Francisco Association of Members of the American Society of Civil Engineers on "The Effects of the San Francisco Earthquake of April 18th, 1906, on Engineering Constructions"; and also read communications on the subject from Messrs. Edwin Duryea, Jr., Franklin Riffle, H. H. Wadsworth, and Emile G. Perrot.

The subject was discussed orally by Messrs. E. W. Stern and J. K. Freitag.

Ballots for membership were canvassed, and the following candidates elected:

AS MEMBERS.

WILLIAM HARRY ARNOLD, Brooklyn, N. Y.
JOHN EDWARD BREEN, Richmond Hill, N. Y.
LAURANCE JOHNSON CARMALT, Brooklyn, N. Y.
RICHARD GRIFFITH DEVELIN, Philadelphia, Pa.
IRVING TUPPER FARNHAM, Newton, Mass.
LEWIS JOHN HENRY GROSSART, Allentown, Pa.
EDMUND PENDLETON HUNTER HARRISON, Philadelphia, Pa.
GEORGE MOREHOUSE HUSS, Big Falls, Minn.
GEORGE PORTLOCK JANES, New York City.
THOMAS KNIGHT MATHEWSON, Panindicuaro, Michoacan, Mexico.
SAMUEL LYNN MORROW, Oglethorpe, Ga.
MARK MAURICE MURTAUGH, Salt Lake City, Utah.
JOHN WESLEY RIPLEY, New York City.
MARK WILLIAM SCHOFIELD, Providence, R. I.

Archibald Alexander Sproul, Peekskill, N. Y.
William Wright Starr, Bridgeport, Conn.
Ernest Frederick Tabor, Corbett, Wyo.
Henry Shotwell Wood, Glen Ridge, N. J.
George Washington Wright, Baltimore, Md.

As Associate Members.

Charles Lambert Addison, Long Island City, N. Y.
Calvin Tomkins Allison, Stony Point, N. Y.
Alexander Conn Beeson, Scenery Hill, Pa.
Harry Alson Briggs, Katonah, N. Y.
Pitson Jay Cleaver, Fort Miller, N. Y.
John T. Collins, Syracuse, N. Y.
Luzerne Simeon Cowles, Boston, Mass.
Fred Wallis Daggett, New York City.
Frank Tenney Darrow, Lincoln, Nebr.
Elliott Johnstone Dent, Washington, D. C.
Robert L'Amy Donald, Portland, Ore.
Preston Burt Easterbrooks, New York City.
Randall Dunbar Gardner, Boston, Mass.
Edward Gray, St. Louis, Mo.
R. Prosper Gustin, Brooklyn, N. Y.
George Rufus Johnson, West Haven, Conn.
Frederick Perceval Kafka, New York City.
John Douglas Matheson, New York City.
Louis Móller, Detroit, Mich.
Parker Cleaveland Newbegin, Houlton, Me.
John Calvin Oakes, Galveston, Tex.
Eduardo Ortiz, Mexico City, Mexico.
Harold Ashton Parsons, Stamford, Conn.
Henry Burger Sauerman, Chicago, Ill.
John Lucian Savage, Boise, Idaho.
Carl Theodore Schwarze, Brooklyn, N. Y.
Edgar Field Smith, New York City.
George Huntington Throop, New York City.
Frederick Howard Tillinghast, Belle Fourche, S. Dak.
Clinton Gambrill Tudor, Reno, Nev.
Gilbert Stoddard Walker, Wheeling, W. Va.
John Bertram Wright, Amsterdam, N. Y.

As Associate.

Frederick William Green, Stamps, Ark.

The Secretary announced:

The transfer of the following candidates by the Board of Direction on April 30th, 1907:

FROM ASSOCIATE MEMBER TO MEMBER.

RICHARD I. DOWNING ASHBRIDGE, East Downingtown, Pa.
JAMES GARNETT BASINGER, New York City.
EDWARD WALLACE BUSH, Hartford, Conn.
GEORGE EDWARD HOWE, Columbus, Ohio.
DEFOREST AUGUSTUS WHEELOCK, Warren, Pa.

The election of the following candidates by the Board of Direction:

AS JUNIORS.

On March 5th, 1907:

GEORGE GLENN MCDANIEL, Mazuma, Nev.
CLAUDE IRVIN RHODES, San Francisco, Cal.
JAMES HERBERT SAWYER, New York City.

On April 2d, 1907:

ELIOT NICHOLS SMITH, New Paltz, N. Y.

On April 30th, 1907:

ALEXANDER SEYMOUR ACKERMAN, Ancon, Canal Zone, Panama.
HAROLD DAYTON ALLEN, Newark, N. J.
RUDOLPH CONRAD BECKER, West Hurley, N. Y.
JOHN RICHARD CAHILL, San Francisco, Cal.
HUBERT HARRY HALL, Dawson, Y. T., Canada.
FREDERICK CLAYTON HARPER, Chicago, Ill.
EARL PATTERSON, Carlsbad, N. Mex.
HORACE EDWARDS PLUMMER, Portland, Ore.
CHARLES GARFIELD RANNEY, Mohawk, N. Y.
GEORGE ARTHUR SISSON, Manila, Philippine Islands.
GEORGE COTTON TUTHERLY, New York City.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

April 30th, 1907.—Past-President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bissell, Bowman, Christie, Hazen, Hodgdon, Knap, Schneider, Smith, Swensson, and Tillson.

Edward P. North, and H. G. Prout, were appointed a Committee to prepare a memoir of the late Charles Paine, Past-President, Am. Soc. C. E.

The Secretary reported that the painting and decoration of the interior of the addition to the Society House, and the re-decoration of the original part, are practically completed.

The painting necessary to put the exterior of the whole house in good order was authorized.

Applications were considered, and other routine business transacted.

Five Associate Members were transferred to the grade of Member, and eleven candidates for Junior were elected.

Adjourned.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, June 5th, 1907.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper entitled "A Solution of the Problem of Determining the Economic Size of Pipe for High-Pressure Water-Power Installations," by Arthur L. Adams, M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings*.

Wednesday, September 4th, 1907.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper entitled "Comparison of Rainfall and Run-Off in the Northeastern United States," by John C. Hoyt, Assoc. M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings*.

Wednesday, September 18th, 1907.—8.30 P. M.—At this meeting a paper entitled "A Description of the Recently Installed Sewage Disposal Works for the Village of Ballston Spa, New York," by G. L. Robinson, Assoc. M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings*.

ANNUAL CONVENTION.

In answer to the preliminary circular, 68 members of the Society have stated their intention to make the trip to Mexico, accompanied by 40 members of their families, making 108 persons now (May 9th, 1907) scheduled for attendance. These figures do not include any of the membership living in Mexico, and, in view of the fact that the circular did not insist upon replies prior to May 15th, the above figures indicate that the attendance will be large.

On this basis it seems safe to say that a special train will be arranged for, running directly from St. Louis to the City of Mexico. This matter has already been taken up, and as soon as the arrangements can be perfected, and a schedule fixed, a circular giving the whole matter in detail will be mailed to all members, so that they may reserve accommodations, etc.

As this circular will contain all the latest information in regard to arrangements for the Convention, a further statement in detail will not be attempted here.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all meetings:

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Society of Engineers, 17 Victoria Street, Westminster, S. W., England.

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Civil Engineers' Club of Cleveland, 718 Caxton Building, Cleveland, Ohio.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa.

Engineers' Society of Western Pennsylvania, 803 Fulton Building, Pittsburg, Pa.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

Louisiana Engineering Society, 604 Tulane-Newcomb Building, New Orleans, La.

Engineers' Club of Central Pennsylvania, Corner Second and Walnut Streets, Harrisburg, Pa.

Engineers' and Architects' Club of Louisville, Ky., 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

Teknisk Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Société des Ingénieurs Civils de France, 19 Rue Blanche, Paris, France.

Svenska Teknologföreniqen, Brunkebergstorg 18, Stockholm, Sweden.

Institute of Marine Engineers, 58 Romford Road, Stratford, London, E., England.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Pacific Northwest Society of Engineers, 617–618 Pioneer Building, Seattle, Wash.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Memphis Engineering Society, Memphis, Tenn.

Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

The Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Institution of Engineers of the River Plate, Buenos Aires, Argentine Republic.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Cleveland Institute of Engineers, Middlesbrough, England.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Rochester Engineering Society, Rochester, N. Y.

Brooklyn Engineers' Club, 197 Montague Street, Brooklyn, N. Y.

Montana Society of Engineers, Butte, Montana.

SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

In reference to this work, the Appendix* to the Annual Report of the Board of Direction for the year ending December 31st, 1906, contains a summary of all searches made to that date.

* *Proceedings*, Vol. XXXIII, p. 20 (January, 1907).

ANNUAL REUNION OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS RESIDING IN WASHINGTON, D. C.

On March 23d, 1907, the members of the American Society of Civil Engineers residing in Washington, D. C., held their annual reunion and banquet, forty-two persons being present.

The local committee of arrangements consisted of Alexander Mackenzie, Chairman; H. M. Wilson, Secretary; and Messrs. D. S. Carll, D. E. McComb, and F. H. Newell. Mr. C. E. Grunsky was toast-master.

The speakers were:

William H. Wiley, on "Relations of the Scientific Press to Engineering";

John F. Hayford, on "Science and the Engineering Profession";

M. O. Leighton, on "Water Supplies of the United States";

A. M. Phillips, on "Rainfall and Sewer Capacities";

J. S. Sewell, on "Fire-proof Construction";

F. H. Newell, on "The Engineering Profession";

W. Crozier, on "Ordnance Engineering";

H. M. Wilson, on "Drainage of Swamps and Overflowed Lands of the United States."

All the speeches were brief, and in a happy strain. After the banquet and speeches, the following were elected as members of the committee for the ensuing year: Mr. F. H. Newell, Chairman; Messrs. John F. Hayford, F. L. Averill, J. S. Sewell, and C. B. Hunt.

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

San Francisco, Cal.

(Abstract.)

April 19th, 1907 —The twelfth regular meeting of the San Francisco Association of Members, Am. Soc. C. E., was held; A. L. Adams, President, in the chair; Franklin Riffle, Secretary; and present, also, 32 members and 16 guests.

The entire evening was devoted to a discussion of the effects of the earthquake of April 18th, 1906, on engineering construction. Written discussions from Messrs. Edwin Duryea, Jr., Franklin Riffle and H. H. Wadsworth, were presented, and the subject was discussed orally by Messrs. L. E. Hunt, Luther Wagoner, P. E. Harroun, Edwin Duryea, Jr., A. M. Bienenfeld, B. Bienenfeld, W. W. Harts, W. F. Whitaker, S. G. Hindes, E. A. Rix, E. T. Thurston, Jr., J. D. Galloway and C. B. Wing.

Adjourned.

ACCESSIONS TO THE LIBRARY.

From April 10th to May 6th, 1907.

DONATIONS.*

BRAYTON STANDARDS.

A Pocket Companion for the Uniform Design of Reinforced Concrete. By Louis F. Brayton. Leather, 6 x 4 in., illus., 131 pp. Minneapolis, 1907. $3.00 net.

The author, in the preface to this work, states that the object of the book is to furnish a guide for reinforced concrete design for engineers and architects who have not made a specialty of this subject. The methods of construction shown are not merely theoretical, but have been put into practice and proven to be efficient. The tables have been designed with a practical knowledge of the contracting side of the design, and the question of the building laws of the various cities has also been taken into consideration in their compilation, in order to make them of more practical value to the user. Plain round bars are advocated by the author, and it is said that, by placing them as indicated in the book, they will accomplish every duty required of them. There is no objection made, however, to plain, twisted square bars, or to some forms of patented bars, when such are considered necessary to aid the adhesion of the concrete. The Contents are: Principles of Design; The Theory of the Beam; The Location of the Steel; Distribution of Load in a Rectangular Panel; Slab Reinforcement; Bending Moment in Slabs for Various Types of Reinforcement; Bending Moment in Slabs for Various Loads and Spans; Properties of Slabs; Moment of Resistance of Slabs; Capacities of Slabs; The Design of Beams; Standard Beam Reinforcement; Bending Moment in Beams; Four Rod Type of Beam; Six Rod Type of Beam; Eight Rod Type of Beam; Shear Loops in Beams; Columns; Details of Hooped Columns; Column Tables; Footings; Base Plates; Stairs; Construction of Forms; Form Details; Proportions of Materials in Concrete; What Bars to Use; Weights and Areas of Square and Round Bars; Area of Round Bars per Foot Width; Tension in Round Bars per Foot Width; Adhesion of Concrete to Rods; Shop Details; Standard Types of Bars; Specification for Reinforced Concrete.

LONG-DISTANCE ELECTRIC POWER TRANSMISSION.

Being a Treatise on the Hydro-Electric Generation of Energy; Its Transformation, Transmission, and Distribution. By Rollin W. Hutchinson, Jr. Cloth, 8 x 5 in., illus., 5 + 345 pp. New York, D. Van Nostrand Company, 1907. $3.00 net.

The object of this book, as stated in the preface, is to furnish, to engineers and students, concise information on the kinds of machinery and apparatus used in hydro-electric, high-tension engineering, and on the construction and operation of high-potential transmission properties. It is intended as a reference book for engineers and a textbook for students, but as such the author does not claim that it is an exhaustive treatise on the subject of high-tension power transmission. The first three chapters include a brief discussion of the principles involved in the construction and operation of the hydraulics of high-tension generating plants. Generators, switches, etc., and the laws governing the transmission of energy are treated in a concise manner, a knowledge of alternating currents and polyphase machinery being presupposed. At the end of each chapter, a short bibliography of the subject treated is given. The Contents are: Laws of Hydraulics; Applied Hydraulics; Hydraulic Machines and Accessory Apparatus; Generators, Switches, and Protective Devices; Laws Governing Transmission of Energy; The Transmission Line; Transformers; Motors; Converters; Practical Plants; Distinctive Features of Prominent Long-Distance Transmissions. There is an index of five pages.

DESIGN OF A RAILWAY BRIDGE PIER.

By Charles Derleth, Jr., Assoc. M. Am. Soc. C. E. Paper, 10 x 7 in., illus., 24 pp. New York, Engineering News Publishing Company, 1907. 50 cents net.

The senior students in the College of Civil Engineering of the University of California make a complete design of the metal superstructure for an in-

* Unless otherwise specified, books in this list have been donated by the publisher.

clined upper chord, double-track railway bridge of about 300 ft. in span length. This pamphlet, it is stated, gives the calculations for a first study for an intermediate pier to carry a superstructure as designed by these students. It was first published in the *California Journal of Technology*, and is now reprinted in separate form because of its value, especially to students, as a study on the subject of bridge-pier design. The proposed pier is assumed to rest on a rock, and the caisson is of steel, the main parts being designed in sufficient detail to satisfy all stress conditions. The calculations, as given, are based upon conditions found for Pier 8 of the Havre de Grace Bridge of the Baltimore and Ohio Railroad. The Contents are: Introduction; General Proportions of Proposed Pier; Specifications; Neck Section of Pier; General Stability of Pier; Horizontal Forces Acting Upon Pier and Superstructure; Stability of Section *MN*; Stability of Caisson-Roof Section; Stability of Pier at Bed-Rock; Batters and Their Effect on the Stability of Piers; Flotation of Caisson; Weight Necessary to Sink Caisson; Design of Caisson; Coffer-Dams, Shafts, Locks, and Power Plant; Bill of Approximate Costs; References.

MODERN AMERICAN LATHE PRACTICE.

By Oscar E. Perrigo. Cloth, 9 x 6 in., illus., 424 pp. New York, The Norman W. Henley Publishing Co., 1907. $2.50.

These pages include, in a comprehensive manner, a history of the origin and development of the lathe from the earliest times to the present day. The effects of the lathe on manufacturing interests are discussed briefly, and a description of its practical use on the various classes of work is given. Lathe design is thoroughly discussed, including back gearing, driving cones, thread cutting gears, etc. The various types of lathes, as manufactured by different builders, are classified, their essential differences specified, and their special features of design, construction and use commented upon briefly. The chapter headings are: History of the Lathe up to the Introduction of Screw Threads; The Development of the Lathe since the Introduction of Screw Threads; Classification of Lathes; Lathe Design: The Bed and Its Supports; Lathe Design: The Head-Stock Casting, the Spindle and the Spindle Cone; Lathe Design: The Spindle Bearings, the Back Gears and the Triple Gear Mechanism; Lathe Design: The Tail-Stock, the Carriage, the Apron, etc.; Lathe Design: Turning Rests, Supporting Rests, Shaft Straighteners, etc.; Lathe Attachments; Rapid Change Gear Mechanisms; Lathe Tools, High-Speed Steels, etc.; Testing a Lathe; Lathe Work; Engine Lathes; Heavy Lathes; High-Speed Lathes; Special Lathes; Regular Turret Lathes; Special Turret Lathes; Electrically Driven Lathes. There is an index of eight pages.

STEAM TURBINES.

Practice and Theory. By Lester G. French. Cloth, 9 x 6 in., illus., 6 + 418 pp. Brattleboro, Vt., The Technical Press, 1907. $3.00.

As editor-in-chief of *Machinery*, the author of this book had the opportunity of collecting notes and data on the steam turbine and allied subjects, both during the formative period of the turbine and after it had become a commercial success. It is stated that these notes and data have served as the foundation for this book, and while some of the subject-matter contained in its pages has appeared in *Machinery*, the greater part of it is entirely new. The first chapter is a condensed treatise on the fundamental principles of the steam turbine. In the second chapter, the author reviews steam turbine patents, including all the turbines manufactured in the United States, together with several of the leading English and Continental machines. A description of the Rateau steam accumulator system is also given. Results of tests upon the flow of steam, the action of steam on vanes, and the economic performance of turbines are discussed in following chapters, with a review of tests upon reciprocating engines. The properties of steam, with an explanation of the temperature-entropy diagram, and data upon the specific heat of superheated steam, are treated as preliminary to the calculations upon the flow of steam. The mathematical treatment has been made as simple as possible, illustrative examples being worked out wherever necessary. Two chapters of the book are devoted to the commercial and operative sides of the subject, followed by a description of high-vacuum condensing apparatus. In the last chapter, the development of the marine turbine between 1894 and 1906 is traced, and data upon the performance of steam turbines are given. The Contents are: Steam Turbine Principles; Early Steam Turbine Patents; Simple Impulse Turbines: The DeLaval Steam Turbine; The Pelton and Similar Types; Compound Impulse Turbines: Multicellular Type; Compound Impulse Turbines (Continued); Reaction Turbines: Parsons Turbines; Miscellaneous Turbines and Apparatus; Steam Turbine Performance: Comparisons with the Steam Engine; Steam Turbine Performance (Continued); Experiments on the Flow of Steam; Properties of Steam; Calculations on the Flow of

Steam; Turbine Vanes; High Speed Rotation; Notes on Efficiency and Design; The Commercial Aspect of the Turbine; Care and Management; Condensing Apparatus for High Vacuum; The Status of the Marine Turbine. There is an index of six pages.

UP-TO-DATE AIR BRAKE CATECHISM.

By Robert H. Blackall. Ed. 21, Rev. and Enl. Cloth, 7 x 5 in., illus., 375 pp. New York, The Norman W. Henley Publishing Co., 1907. $2.00.

On the title-page of this book, it is stated that it is a complete study of the equipment manufactured by the Westinghouse Air Brake Company, including the Schedule ET locomotive brake equipment, the K (quick-service) triple valve for freight service, and the cross compound pump. The operation of all parts of the air-brake is explained in detail, and a practical remedy for any defect is given. The book is written in the class-room style and contains nearly two thousand questions with their answers, giving all the information necessary for a railroad man to pass an examination on the subject of air-brakes. The contents have been revised and brought up to date by the addition of an appendix of sixty-seven pages, in which is explained the operation of the improved Westinghouse equipment developed for use on modern locomotives and freight cars. There is an index of about seven pages.

ELECTRIC AND MAGNETIC MEASUREMENTS

and Measuring Instruments. By Frank W. Roller. Cloth, 9 x 6 in., illus., 5 + 398 pp. New York, McGraw Publishing Company, 1907. $3.50.

The subjects discussed in these pages have, it is stated, been written particularly for those who use electric and magnetic measuring instruments. The author states that while the book is not intended as a treatise on the design and construction of such instruments, descriptions of the apparatus, as well as of methods of test, are given. There is an appendix containing a list of the names and addresses of the manufacturers of most of the instruments described and illustrated in the text. The Contents are: Definitions of Units; Laboratory and Commercial Standards of Resistance, Current, E. M. F., Capacity, and Inductance; Galvanometers; Potentiometers; The Measurement of Resistance; Measurement of Current; Measurement of Potentials; Measurement of Power; Measurement of Capacity; Measurement of Inductance; Miscellaneous Determinations; Recording Instruments; Integrating Meters; Maximum Demand Meters; Magnetic Units; Measurement of Field Strength; Measurement of Permeability; Hysteresis; Appendix. There is an index of three pages.

THE MANUFACTURE AND PROPERTIES OF IRON AND STEEL.

By Harry Huse Campbell. Fourth Edition. Cloth, 9 x 6 in., illus., 26 + 639 pp. New York and London, Hill Publishing Company, 1907. $5.00.

The subject-matter of this edition of this work, as stated in the preface, has been carefully revised and enlarged. The book is divided into three parts. Part I is intended as an Introduction to those who are not metallurgists, and contains only the main principles of iron metallurgy. Part II includes the subjects covered in the first edition of "Structural Steel." That portion of Part II which relates to open-hearth furnaces has been condensed from papers contributed by the author to the *Transactions* of the American Institute of Mining Engineers, and portions of other chapters in this section have appeared in the *Transactions* of the American Society of Civil Engineers. The detailed calculations by the method of least squares, contained in Chapter XVII of previous editions, have been omitted in this edition. The Standard Specifications are not printed in full as usual, being, as they are, subject to constant change. A new determination of the effect of certain elements upon steel is given. All the experiments cited were made at The Pennsylvania Steel Works, at Steelton, Pa., and the details of manufacture were carried on under the direct supervision of the author. In Part III, a comparison of the iron industry in different countries is made. The Contents are: Part I, The Main Principles of Iron Metallurgy. Part II, The Metallurgy of Iron and Steel: Primitive Methods of Making Iron; The Blast Furnace; Wrought-Iron; Steel; High-Carbon Steel; The Acid Bessemer Process; The Basic Bessemer Process; The Open-Hearth Furnace; Fuel; The Acid Open-Hearth Process; The Basic Open-Hearth Process; Special Methods of Manufacture and Some Items Affecting the Costs; Segregation and Homogeneity;

Influence of Hot Working on Steel; Heat Treatment; The History and Shape of the Test-Piece; The Influence of Certain Elements on the Physical Properties of Steel; Classification of Structural Steel; Welding; Steel Castings. Part III, The Iron Industry of the Leading Nations; Statistics; Appendix. There is an index of seventeen pages, with indices of tables and figures.

Gifts have also been received from the following:

Aachen-Königl. Technische Hochschule. 1 pam.
Am. Public Works Assoc. 1 bound vol.
Am. Soc. for Testing Materials. 1 vol.
Anderson, J. T. N. 1 bound vol., 1 pam.
Brooklyn Public Library. 1 pam.
Canada-Board of Ry. Commrs. 1 pam.
Chicago, Ill.-Bureau of Statistics and Municipal Library. 1 pam.
Church, G. E. 1 pam.
Civ. Engrs'. Club of Cleveland. 1 pam.
Cleveland, Cincinnati, Chicago & St. Louis Ry. Co. 1 pam.
Conn.-State Board of Health. 1 bound vol.
Copper Range Consolidated Co. 1 pam.
Danforth, Frederick. 1 bound vol., 1 pam.
Delaware & Hudson Co. 1 pam.
Delaware County Inst. of Sci. 1 pam.
Earl, G. G. 12 pam.
Eng. Assoc. of New South Wales. 1 bound vol.
Exploration Co., Ltd. 2 pam.
Fitchburg, Mass.-City Engr. 1 pam.
Gen. Alumni Assoc. of the Univ. of Minnesota. 1 pam.
Grand Rapids & Indiana Ry. Co. 1 pam.
Great Britain-Patent Office. 4 vol., 6 pam.
Hatt, W. K. 1 pam.
Haverhill, Mass.-Board of Water Commrs. 1 pam.
Ill.-Governor. 2 pam.
Ill.-Highway Comm. 1 bound vol.
Ill. Univ.-Eng. Exper. Station. 6 pam.
Inst. of Civ. Engrs. 1 bound vol.
Jaycox, T. W. 1 bound vol.
Joseph Dixon Crucible Co. 1 pam.
Little Falls, N. Y.-Board of Public Works. 1 pam.
Lochridge, E. E. 1 pam.
Maignen, P. A. 1 pam.
Maine-R. R. Commrs. 1 pam.
Mass.-Board of Met. Park Commrs. 1 bound vol.
Mayne, Charles. 1 vol.
Met. West Side Elev. Ry. Co. 1 pam.
Mexican Ry. Co., Ltd. 2 pam.
Mich. Central R. R. Co. 1 pam.
Minnesota Surv. and Engrs. Soc. 1 pam.
Municipal Engrs. of the City of New York. 1 pam.
Nebraska-State Board of Irrig. 1 bound vol.
New Orleans, La.-Sewerage and Water Board. 1 pam.
New South Wales-Bureau of Statistics. 2 vol., 4 pam.
New South Wales-Govt. Board of Inter. Exchanges. 1 bound vol.
New York State-Advisory Board of Cons. Engrs. 1 pam.
New York Central & Hudson River R. R. Co. 1 pam.
New York, Chicago & St. Louis R. R. Co. 1 pam.
New York City Record. 1 bound vol.
North, E. P. 3 pam.
Paterson, N. J.-Taxpayers' Assoc. 1 bound vol.
Platt, T. C. 2 vol.
Rhode Island-State Board of Health. 1 bound vol.
Royal Soc. of New South Wales. 1 vol.
St. Louis, Mo.-Municipal Bridge and Terminals Comm. 3 pam.
Schiffbautechnische Gesellschaft. 1 bound vol.
Siemens-Schuckertwerke. 1 pam.
Smithsonian Inst. 2 bound vol., 1 vol., 2 pam.
Soc. Belge des Ingénieurs et des Industriels. 1 pam.
Soc. of Engrs. 1 pam.
Soc. of Naval Archts. and Marine Engrs. 1 bound vol.
Springfield, Mass.-Board of Water Commrs. 1 pam.
Thompson, Slason. 1 pam.
Trussed Concrete Steel Co. 5 pam.
Union Coll. 1 vol.
U. S. Bureau of Statistics. 2 bound vol., 1 vol.
U. S. Bureau of the Census. 1 bound vol.
U. S. Climatological Service of the Weather Bureau, New Jersey Section. 3 pam.
U. S. Corps of Engrs. 14 specif.
U. S. Forest Service. 4 pam.
U. S. Geol. Survey. 2 bound vol., 2 vol., 11 pam.
U. S. Interstate Commerce Comm. 2 bound vol., 16 pam.
U. S. Lake Survey Office. 1 map.
U. S. Supt. of Documents. 2 vol.
Univ. of Mich. Eng. Soc. 1 pam.
Univ. of Penna. 1 pam.
Univ. of Wis. 1 vol.
Waukegan, Ill.-Board of Water Supply. 1 pam.
Wilmington, Del.-Board of Park Commrs. 1 pam.
Yale Scientific Monthly. 5 vol., 2 pam.

BY PURCHASE.

The Anatomy of Bridge Work. By William Henry Thorpe. London, E. & F. N. Spon, Limited; New York, Spon & Chamberlain, 1906.

The "Engineering" and Electric Traction Pocket-Book. By Philip Dawson. Fourth Edition (Revised and Rewritten). London, Office of *Engineering;* New York, John Wiley and Sons, 1906.

Clays: Their Occurrence, Properties, and Uses, with Especial Reference to those of the United States. By Heinrich Ries. First Edition. New York, John Wiley and Sons; London, Chapman & Hall, Limited, 1906.

Die Assanierung der Städte in Einzeldarstellungen. Band I, Heft 1, Paris; Heft 2, Wien; Heft 3, Zürich. Edited by Dr. Th. Weyl. Leipzig, Wilhelm Engelmann, 1900, '02–03.

A Theoretical and Practical Treatise on the Manufacture of Sulphuric Acid and Alkali, with the Collateral Branches. By George Lunge. 3 vol. in 4. Vol. 1. Third Edition, Revised and Enlarged; Vol. 2 and 3, Second Edition, Revised and Enlarged. London, Gurney & Jackson, 1895–96, 1903.

Commission du Ciment Armé. Expériences, Rapports & Propositions, Instructions Ministérielles Relatives à l'Emploi du Béton Armé. Ministère des Travaux Publics, des Postes et des Télégraphes. Paris, H. Dunod et E. Pinat, 1907.

Rivetage. Par M. Fricker. Paris, Gauthier-Villars; Masson et Cie., 1906.

SUMMARY OF ACCESSIONS.

From April 10th to May 6th, 1907.

Donations (including 27 duplicates)	196
By purchase	12
Total	208

MEMBERSHIP.

ADDITIONS.

MEMBERS.		Date of Membership.
ARNOLD, WILLIAM HARRY. 165 Prospect Park West, Brooklyn, N. Y.		May 1, 1907
ASHBRIDGE, RICHARD I DOWNING. Chf. Engr., New Jersey Short Line R. R., East Downingtown, Pa.	Assoc. M. M.	Sept. 3, 1902 April 30, 1907
BASINGER, JAMES GARNETT. Cons. Civ. Engr., 45 Broadway (Res., 1580 Amsterdam Ave.), New York City.	Assoc. M. M.	Oct. 3, 1900 April 30, 1907
BREEN, JOHN EDWARD. Prin. Asst. Engr., Bay Ridge Impvt., L. I. R. R., Church St., Richmond Hill, N. Y.		May 1, 1907
BUSH, EDWARD WALLACE. Asst. Engr., Conn. River Bridge and Highway Dist. Comm., 39 Willard St., Hartford, Conn.	Assoc. M. M.	April 5, 1899 April 30, 1907
CONSTANT, FRANK HENRY. Prof. of Structural Eng., Univ. of Minnesota, Minneapolis, Minn.	Assoc. M. M.	Dec. 2, 1896 April 2, 1907
FARNHAM, IRVING TUPPER. City Engr., City Hall, West Newton, Mass.		May 1, 1907
GAGEL, EDWARD. Chf. Engr., N. Y., N. H. & H. R. R., 323 Center St., West Haven, Conn.		April 3, 1907
HARRISON, EDMUND PENDLETON HUNTER. Second Vice-Pres. and Engr., Eyre-Shoemaker, Inc., Contrs., 900 Arcade Bldg., Philadelphia, Pa.		May 1, 1907
JANES, GEORGE PORTLOCK. 124 West 45th St., New York City.		May 1, 1907
LEWIS, CLARENCE CHARLES. Care, J. G. White & Co., Ltd., 25 de Mayo, 206, Montevideo, Uruguay.		Feb. 6, 1907
LIVINGSTON, ARCHIBALD ROGERS. Supt., The Empire Zinc Co., Canon City, Colo.		April 3, 1907
MCCRICKETT, THOMAS FRANCIS. Care, Russel Wheel & Foundry Co., Detroit, Mich.		Jan. 2, 1907
MORSE, GEORGE FREDERICK. Asst. Engr., C. R. R. of N. J., Foot of West 23d St., New York City.		April 3, 1907
RIPLEY, JOHN WESLEY. 82 Beaver St., New York City.		May 1, 1907
SCHOFIELD, MARK WILLIAM. 27 Exchange St., Providence, R. I.		May 1, 1907
STARR, WILLIAM WRIGHT. City Surv., Room 20, City Hall, Bridgeport, Conn.		May 1, 1907
STONE, HENRY MORTON. Dist. Engr., C., R. I. & P. Ry., Cedar Rapids, Iowa.		April 3, 1907

MEMBERS (*Continued*).

		Date of Membership.
WHEELOCK, DE FOREST AUGUSTUS. City Engr., 15 Third St., Warren, Pa....	Assoc. M.	Feb. 3, 1897
	M.	April 30, 1907
WOOD, EDWARD NATHAN. 2516 Indiana Ave., Chicago, Ill.		Dec. 5, 1906

ASSOCIATE MEMBERS.

BEESON, ALEXANDER CONN. Scenery Hill, Washington Co., Pa.		May 1, 1907
CLEAVER, PITSON JAY. Asst. Engr. in Chg., Contract No. 3, N. Y. State Barge Canal, Fort Miller, N. Y.	Jun.	April 4, 1899
	Assoc. M.	May 1, 1907
COLLINS, JOHN T. West Shore Station, Syracuse, N. Y..		May 1, 1907
COWLES, LUZERNE SIMEON. 101 Milk St., Boston, Mass..		May 1, 1907
DAVIS, GEORGE ROBERT. Care, U. S. Geological Survey, Sacramento, Cal.		April 3, 1907
DENT, ELLIOTT JOHNSTONE. 1st Lieut., Corps of Engrs., U. S. A., 22d and K Sts., N. W., Washington, D. C.		May 1, 1907
ELLIS, CHARLES ALTON. Box 156, Ambridge, Pa.		April 3, 1907
FRY, LESLIE MONROE. Box 841, Crookston, Minn	Jun.	June 6, 1905
	Assoc. M.	April 3, 1907
GARDNER, RANDALL DUNBAR. Senior Asst. Engr., Room 60, City Hall, Boston, Mass.		May 1, 1907
GRIFFITH, JOHN HOWELL. Bellevue Station, Allegheny, Pa.		April 3, 1907
HODGDON, JOHN BREWSTER. 1624 Joplin St., Galena, Kans.		April 3, 1907
HORTENSTINE, HENRY ROBERTS. U. S. Naval Station, New Orleans, La.		April 3, 1907
HOWELL, WILLIAM AUGUSTUS. City Hall, Newark, N. J.		April 3, 1907
JOHNSON, GEORGE RUFUS. 700 Washington Ave., West Haven, Conn.		May 1, 1907
KAFKA, FREDERICK PERCEVAL. 609 West 138th St., New York City.		May 1, 1907
KINNE, GEORGE WHITNEY. 24 Parker Ave., Poughkeepsie, N. Y.		Dec. 5, 1906
MATHESON, JOHN DOUGLAS. Asst. Engr., N. Y. C. & H. R. R. R. Co., 335 Madison Ave., Room 1136, New York City.	Jun.	Mar. 3, 1903
	Assoc. M.	May 1, 1907
MOBBERLY, HENRY PEYTON. Chf. Engr., La. East & West R. R. Co., Bunkie, La.		April 3, 1907
SEERY, FRANCIS JOSEPH. Instr. in Civ. Eng., Cornell Univ., 113 Dryden Rd., Ithaca, N. Y.		April 3, 1907
SELMER, JENS KRISTIAN. Apartado 1336, City of Mexico, D. F., Mexico.		Nov. 7, 1906
SOUTHER, THEODORE WHEELER. West Point, N. Y.		Mar. 6, 1907

ASSOCIATE MEMBERS (*Continued*).

	Date of Membership.
TAYLOR, ALEXANDER JENIFER. Engr. in Chg. of Sewers, Wilmington, Del. { Jun. / Assoc. M.	Oct. 3, 1899 / April 3, 1907
TORRE, ALBERTO DE LA. Apartado No. 92, Bogota, Colombia	Oct. 3, 1906
WALKER, GILBERT STODDARD. 1050 Main St., Wheeling, W. Va	May. 1, 1907
WHITE, WILLARD OLNEY. Engr., Tower Hill-Connellsville Coke Co., Republic, Fayette Co., Pa	April 3, 1907
WRIGHT, JOHN BERTRAM. 16 Arnold Ave., Amsterdam, N. Y	May 1, 1907

ASSOCIATE.

SMITH, ALBERT. Assoc. Prof. of Civ. Eng., Purdue Univ., 801 South St., Lafayette, Ind	April 3, 1907

JUNIORS.

ALLEN, HAROLD DAYTON. 27 Wakeman Ave., Newark, N. J	April 30, 1907
BOYLE, OLIN MCCLINTOCK, Jr. Greenwater, Inyo Co., Cal	Mar. 5, 1907
HERRON, GEORGE MERRICK. Care, U. C. Co., Vallecito, Cal	April 2, 1907
HOLBROOK, ARTHUR RAYMOND. Care, Board of Water Supply, 299 Broadway, New York City	April 2, 1907
KING, ERIC TURE. Cornwall-on-Hudson, N. Y	Feb. 5, 1907
MCDANIEL, GEORGE GLENN. Mazuma, *via* Lovelock, Nev.	Mar. 5, 1907
MCMENIMEN, WILLIAM VINCENT. 509 West 135th St., New York City	April 30, 1907
MITCHELL, WILLIAM WASHINGTON. Care, N. P. Ry. Co., Hawley, Minn	April 2, 1907
PECK, CHARLES FRANKLIN. 323 N. 13th St., Lincoln, Nebr	April 2, 1907
RHODES, CLAUDE IRVIN. 152 Twelfth Ave., San Francisco, Cal	Mar. 5, 1907
RICE, JOHN MARIE THOMAS. 5307 Butler St., Pittsburg, Pa	April 2, 1907
RICE, ROWLAND GRENVILLE. 192 Summer St., Stamford, Conn	Mar. 5, 1907
SAWYER, JAMES HERBERT. 60 Wall St., New York City.	Mar. 5, 1907
SMITH, FORREST LEIGH. 102 Smith St., Perth Amboy, N. J	April 30, 1907
TUTHERLY, GEORGE COTTON. Room 2032, Park Row Bldg., New York City	April 30, 1907

JUNIORS (*Continued*). Date of Membership.

WILEY, HUGH LEMUEL. G. T. P. Ry., Fort William, Ont., Canada..... April 2, 1907

WILLCOMB, GEORGE EDWARD. 273 Hamilton St., Albany, N. Y..... Oct. 30, 1906

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BATES, ONWARD. (*Vice-President*). 355 Dearborn St., Chicago, Ill.

BELL, HENRY PURDON. Trent Canal, Campbellford, Ont., Canada.

BISHOP, HUBERT KEENEY. 19 So. Hawk St., Albany, N. Y.

BROWNELL, ERNEST HENRY. Civ. Engr., U. S. N., Navy Yard, Brooklyn, N. Y.

COFFIN, AMORY. 362 South Orange Ave., South Orange, N. J.

COWLES, WALTER LINSLEY. Cons. Engr.; Secy., D. F. Holman Ry. Tracklayer Co., 1103 Ellsworth Bldg., Chicago, Ill.

DAVIS, CHARLES HENRY. South Yarmouth, Mass.

DENNIS, ARTHUR CRISFIELD. Care, West. Pac. Ry., Amedee, Cal.

DOCKWEILER, JOHN HENRY. Cons. Engr., 531 Clayton St., San Francisco, Cal.

DUNHAM, LEWIS AUGUSTUS. 42 Broadway, New York City.

FICKES, CLARK ROBINSON. Iowa City, Iowa.

GATES, HORACE DELPHOS. Cor. College and Claremont Avenues, Oakland, Cal.

GORDON, CHARLES EDWARD. Engr., U. S. Reclamation Service, in Chg., Garden City Project, Deerfield, Kans.

GREGORY, LUTHER ELWOOD. Civ. Engr., U. S. N., Navy Yard, Brooklyn, N. Y.

GUMAER, EDWARD BENNET. Allenhurst, N. J.

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IVES, ARTHUR STANLEY. 33 Sidney Pl., Brooklyn, N. Y.

KEITH, GEORGE THOMAS. Res. Engr., Water Supply, Barge Canal Office, North Tonawanda, N. Y.

KIEFFER, STEPHEN EPHRAIM. 2404 Dana St., Berkeley, Cal.

LEBARON, JOHN FRANCIS. R. F. D. No. 3, Chardon, Ohio.

MEMBERS (*Continued*).

LLEWELLYN, FRANCIS JOHN. Div. Contr. Mgr., Am. Bridge Co. of N. Y., Commercial National Bank Bldg., Chicago, Ill.

MARTIN, WISNER. Supt. of Constr., Stone & Webster Eng. Corp., Harvard Power Station Extension (Res., 1636 Massachusetts Ave.), Cambridge, Mass.

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OWENS, HENRY KINDER. Cons. Civ. Engr., Hartford Irrig. & Power Co., Pasco Power & Water Co., 24 Seattle National Bank Bldg., Seattle, Wash.

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TOUCEDA, ENRIQUE AUGUSTO. Chemist and Metallurgist, Broadway, Cor. Thacher St., Albany, N. Y.

VAN HOESEN, EDMUND FRENCH. Care, Board of R. R. Commrs., Albany, N. Y.

WAIT, JOHN CASSAN. Attorney and Counseller at Law (Wait & Foster), 38 Park Row, New York City.

WALKER, JOHN SHAW. Structural Engr. and Archt., Freedman Bldg., Hay St., Perth, Western Australia.

WEINHAGEN, FRED. Pres., Wisconsin Bridge & Iron Co., 606 Colby & Abbott Bldg., Milwaukee, Wis.

ASSOCIATE MEMBERS.

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DEGRAFF, HARRY WESTBROOK. Care, A. G. & P. Co., Comstock, Washington Co., N. Y.

FARNHAM, CHARLES HENRY. Div. Engr., Negros Div., Philippine Ry. Co., J. G. White & Co., Engrs. and Contrs., Bacolod, Occ. Negros, Philippine Islands.

FITZGERALD, CHRISTOPHER COLUMBUS. Div. Engr., Norfolk & South. R. R. Co., Washington, N. C.

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FRENCH, FRANK CHAUNCEY. Senior Inspecting Engr., Philippine Railways, Cebu, Philippine Islands.

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OINOUYE, CHIKAO. With Penn Bridge Co., Beaver Falls, Pa.

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SAWYER, WILBUR CYRUS. Box 937, Pomona, Cal.

SEASTONE, CHARLES VICTOR. 401 State St., Madison, Wis.

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STONE, WILLARD WILBERFORCE. Asst. Engr., Board of Water Supply, New York City, 940 Orchard St., Peekskill, N. Y.

SUMNER, ROBERT SWAN. 204 Commonwealth Bldg., Denver, Colo.

WALKER, JOSEPH MILTON. Chf. Engr., Lima & Toledo Ry. Co., Waterville, Lucas Co., Ohio.

WILKERSON, THOMAS JEFFERSON. Engr., Bridge Designs and Estimates, Am. Bridge Co., 802 Frick Bldg.; Address, Box 33, Forbes Station, Pittsburg, Pa.

ASSOCIATES.

LA FARGE, OLIVER HAZARD PERRY. Box 930, Seattle, Wash.

SCHNEIDER, EDWARD JOHN. Contr. Mgr., Am. Bridge Co. of N. Y., 16th and Folsom Sts., San Francisco, Cal.

JUNIORS.

BAKER, HAROLD JAMES MANNING. No. 4, The Knickerbocker, 1022 Union St., Seattle, Wash.

BAKER, SHELDON KING. Asst. Engr., U. S. Reclamation Service, Ridgelawn, Mont.

BALDRIDGE, JAMES RAMSEY. Care, Turner Forman Concrete Steel Co., 12th and Chestnut St., Philadelphia, Pa.

BECKER, ELVIN JAY. Topographical Draftsman, Board of Water Supply, New York City, Waterford, N. Y.

BELZNER, THEODORE. Insp. of Steel, Blackwells Island Bridge (No. 4), Dept. of Bridges, 56 Sutton Pl. (Res., 614 West 135th St.), New York City.

BIRCH-NORD, CARL WILLIAM. With Am. Bridge Co., Room 1301, Commercial National Bank Bldg., Chicago, Ill.

BRADY, JOSEPH. Asst. Engr., Rapid Transit R. R. Comm., 320 Broadway, New York City.

CAMERON, KENNETH MACKENZIE. Box 456, Ellsworth, Me.

CAMPBELL, HENRY AVERY. Sausalito, Cal.

JUNIORS (*Continued*).

DUNCAN, JAMES HARPER. Chf. Draftsman, Bangor & Aroostook R. R., Searsport, Me.

ELTINGE, ORVILLE LAMONT. Perth Hotel, R. F. D. Route No. 4, Amsterdam, N. Y.

FOLLANSBEE, ROBERT. Asst. Engr., U. S. Geological Survey, Montana National Bank Bldg., Helena, Mont.

FORD, HARRY CLIFFORD. 440 West 22d St., New York City.

FOWLER, FREDERICK HALL. 221 Kingsley Ave., Palo Alto, Cal.

HALL, JULIUS REED. Engr., Hall Machine Co., 739 Monadnock Blk., Chicago, Ill.

HASBROUCK, OSCAR. 143 Eighth St., Troy, N. Y.

HUBER, WALTER LEROY. 1001 Atlas Bldg., San Francisco, Cal.

JARVIS, CLARENCE SYLVESTER. Care, U. S. Reclamation Service, Provo, Utah.

JOHNSON, LUTHER ELMAN. Care, U. S. Reclamation Service, Deerfield, Kans.

LUDLOW, JUSTIN WYMAN. Engr., Unit Concrete Steel Co., 1605 Heyworth Bldg., Chicago, Ill.

LYDSTON, WALTER EDWARD. Asst. Engr., N. Y. C. &. H. R. R. R., Ossining, N. Y.

LYNCH, EDWIN LEWIS. Junior Asst. Engr., Dept. of Public Works, 23 Emerson St., Portland, Me.

MCLURE, NORMAN ROOSEVELT. New Liverpool, Que., Canada.

MATLAW, ISAAC SOLON. Leveler, Dept. of State Engr. and Surv., Waterford, N. Y.

MERRILL, ROBERT HALL. Asst. Engr., Barge Canal Office, Fort Hunter, N. Y.

RACKLE, OSCAR WILLIAM. Head Draftsman, Rhode Island State Board of Public Roads; Asst. Instr. of Civ. Eng., Brown Univ., Suite 13, Brunonia Hall, Providence, R. I.

RICH, MELVIN S. The Carlton, Toledo, Ohio.

SMITH, ROBERT MACKINLAY. 4233 McPherson Ave., St. Louis, Mo.

TOMBO, CARL. Box 30, Station J, New York City.

TRUE, ALBERT OTIS. 3 Bowdoin St., Newton Highlands, Mass.

VAN KIRK, CHARLES HINKLEY. The Kaw Gas Co., Dept. E, Independence, Kans.

WILSON, SAMUEL. Care, Spanish-American Iron Co., Mayari, Cuba.

DEATHS.

FREEMAN, FRANK LESLIE. Elected Associate, November 5th, 1895; died March 3d, 1907.

GRIFFIN, EUGENE. Elected Member, June 7th, 1899; died April 10th, 1907.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(April 6th to May 4th, 1907.)

NOTE.—*This list is published for the purpose of placing before the members of the Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(1) *Journal*, Assoc. Eng. Soc., 31 Milk St., Boston, Mass., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Blk., Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.

(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 803 Fulton Bldg., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne, England.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Industrial World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(70) *Engineering Review*, New York City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.
(72) *Electric Railway Review*, Chicago, Ill., 10c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, Ill., 10c.
(77) *Journal*, Inst. Elec. Engrs., London, England.
(78) *Beton und Eisen*, Vienna, Austria.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie-Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Dinglers Polytechnisches Journal*, Berlin, Germany.
(83) *Progressive Age*, New York City, 15c.
(84) *Le Ciment*, Paris, France.
(85) *Proceedings*, Am. Ry. Eng. and M. of W. Assoc., Chicago, Ill.
(86) *Engineering World*, Chicago, Ill.
(87) *Railway Maintenance and Structures*, New York City, 10c.

LIST OF ARTICLES.

Bridge.

The Design of a Two-Hinged Spandrel-Braced Steel Arch.* Ralph Freeman, Stud. Inst. C. E. (63) Vol. 167.
Replacement of Bridges and Allied Structures. Herman K. Higgins. (Paper read before the Boston Soc. of Civil Engineers.) (1) Mar.
Strengthening Girder Bridges on the Madras Railway.* Edward W. Stoney, M. Inst. C. E. (11) Mar. 29.
Concrete Arches with Old Rail Reinforcement.* C. L. Slocum. Assoc. M. Am. Soc. C. E. (Abstract of paper read before the Conn. Soc. of Engrs.) (13) Apr. 11.
The Auld Brig O' Ayr.* (11) Apr. 12.
The Strauss Trunnion Bascule Bridge near Rahway, N. J.* (14) Apr. 13.
The Anchorage for Brooklyn Bridge Number Three.* Charles M. Ripley. (86) Apr. 19.
Some Three-Hinged Concrete Arches in Germany.* (13) May 2.
The Hudson River Bridge at Sandy Hill, N. Y.* (14) May 4.

Electrical.

Lightning Phenomena in Electric Circuits.* Charles P. Steinmetz. (42) Mar.
Zigzag Leakage of Induction Motors.* R. E. Hellmund. (42) Mar.
Some Phases of Heavy Electric Traction. W. J. Wilgus and others. (65) Mar.
The Mechanism of Power Transmission from Electric Motors.* Wilfrid L. Spence. (Abstract of paper read before the Inst. of Engrs. and Shipbuilders in Scotland.) (22) Mar. 29.
Extra-High-Tension Switch Gear.* (11) Serial beginning Mar. 29.
Modern Electrically-Driven Cranes.* (26) Apr. 5.
The Hankow Light and Power Co.'s Works, China.* (26) Apr. 5.
The Kuhlo System of Wiring with Sheathed Conductors.* M. Biske. (Abstract from *Bulletin* of the Assoc. des Ing. Elec.) (73) Apr. 5.
The Hydro-Electric and Water Power Plant of a Large Paper Mill.* (14) Apr. 6.
Electrical Features of the Engineering Societies Building.* (27) Apr. 6.
Brush Holders and Brushes for 500-Volt Motors.* Eugene C. Parham. (27) Serial beginning Apr. 6.
Soil Electrolysis with Formation of a Liquid Sodium Potassium Alloy. Henry Bassett, Jr. (Abstract of paper read before the Soc. of Chemical Industry.) (73) Apr. 12.

* Illustrated.

Electrical—(Continued).

The Electrical Equipment of a Buenos Aires Granary.* (26) Apr. 12.
Two-Pole Turbo-Alternator with Stationary Field and Magnetically-Shunted Exciter.* A. Heyland. (73) Apr. 12.
Utilization of Drainage Canal Power for Chicago Municipal Lighting.* (27) Apr. 13.
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COMPARISON BETWEEN RAINFALL AND RUN-OFF IN THE NORTHEASTERN UNITED STATES.

By John C. Hoyt, Assoc. M. Am. Soc. C. E.

To Be Presented September 4th, 1907.

Until within a comparatively recent date it has been the common practice of engineers to estimate the discharge of surface streams from precipitation data. This practice was necessary because of the comparatively few reliable data in regard to stream flow, and, although responsible for many wild estimates, it has served a useful purpose and has become so common that many engineers have persisted in its use even when reliable run-off data were available.

During the past ten years a large amount of information has been collected by the United States Government and by private parties, in regard both to precipitation and to stream run-off, which makes it now possible to compare in detail the relation between these two phenomena. Such a study, for the northeastern portion of the United States, is herein presented.

The tables* used for the comparison show, not only the relation of the rainfall to the run-off, but have also the additional practical value of serving as a basis for predicting the average run-off which may be expected in the areas which have been investigated.

* Acknowledgment is made to Mr. Fred F. Henshaw for his assistance in the preparation of the tables.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

At the start it was intended to extend the comparisons to all sections of the United States where run-off data are available. The time required for such an extensive study would have been so great, however, that it has been decided to present the data now in hand, covering only the northeastern portion of the United States.

Rainfall Data.

The rainfall data have been collected by the United States Weather Bureau. In using them, the following conditions must be considered:

The plan of the Weather Bureau is to establish a precipitation station in each county; therefore, in most of the areas considered, the horizontal distribution of the stations is uniform and quite representative. This is not generally the case, however, with the vertical distribution of the stations, as the location of the gauge depends in a large measure on the accessibility of a reliable observer and a telegraph station, and these are not generally available at the higher altitudes. Most of the stations have been located at low or medium elevations; and, as but few definite data are available on the effects of elevation on precipitation, it has been impracticable in this study to allow for this factor.

A rain gauge collects the precipitation that falls on a few square inches of surface; therefore, in order to measure accurately the average precipitation over a large area, there should be many rain gauges. As the gauges are always few in number, an extreme precipitation occurring on a comparatively small area may not be recorded.

No satisfactory method has yet been devised for obtaining reliable data in regard to precipitation in the form of snow, and practically no data have been collected to show the quantity of water stored as snow at the end of each month. There is introduced, therefore, an uncertainty in the winter records which makes it necessary to study the winter period as a whole.

It is assumed that for any month the mean rainfall over the whole area is the mean of the monthly rainfalls at the various stations in that area. Based upon this assumption, the monthly and yearly rainfalls have been determined for each of the years when run-off records were available.

Records of precipitation were lacking for many months in these years. In all such cases the mean of the available records was taken as the mean for the month in question; therefore, it may happen that the mean for January may be obtained from records of 20 stations, while the mean for February may come from only 15 stations. In Table 2 the last column, "Number of precipitation stations," shows the least number of stations used for any month of the year.

Run-off Data.

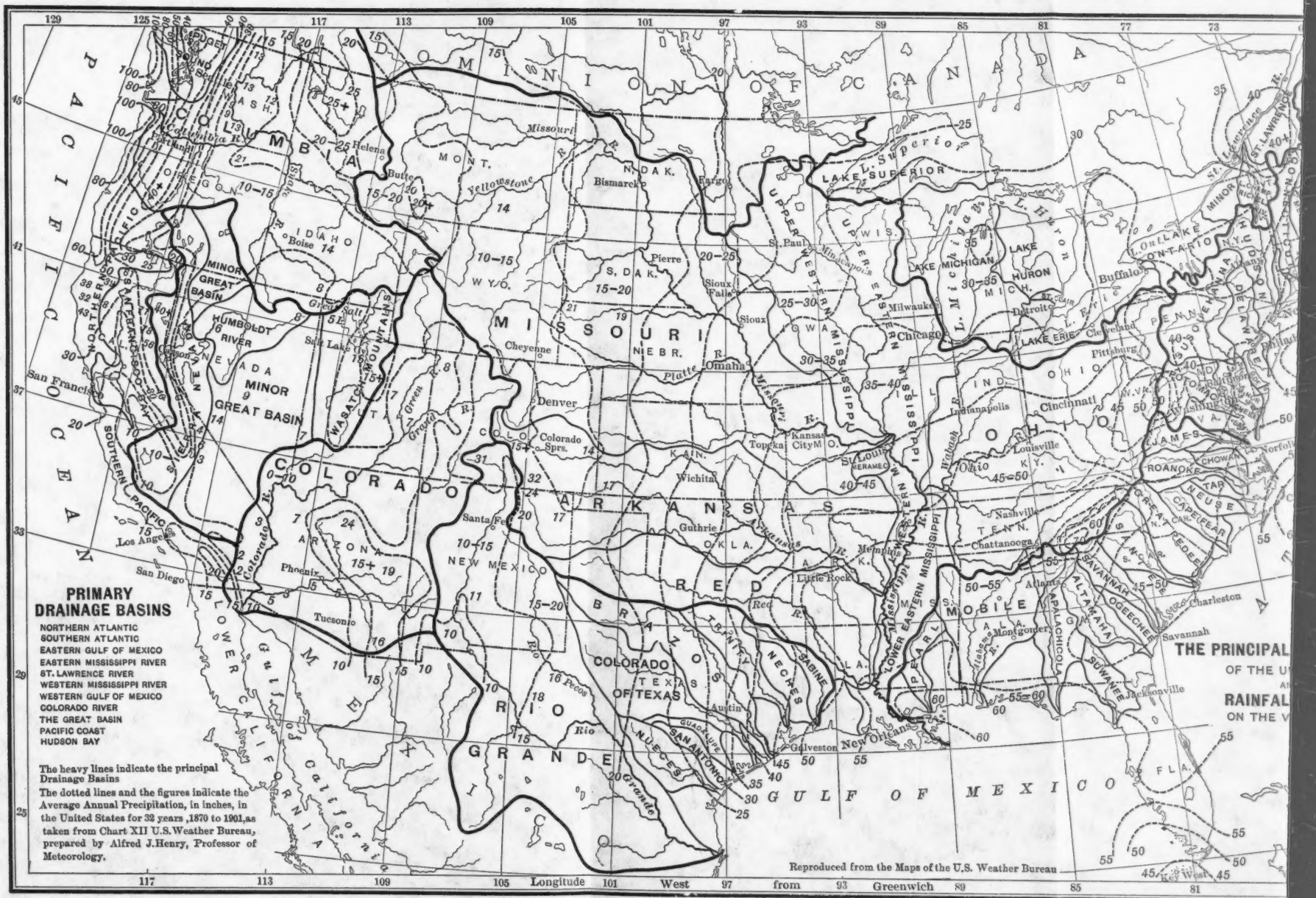
The run-off data used in this study have been taken from the records of the United States Geological Survey. The data, in all cases, have been reviewed and brought to a uniform basis, special attention being given to the winter estimates.

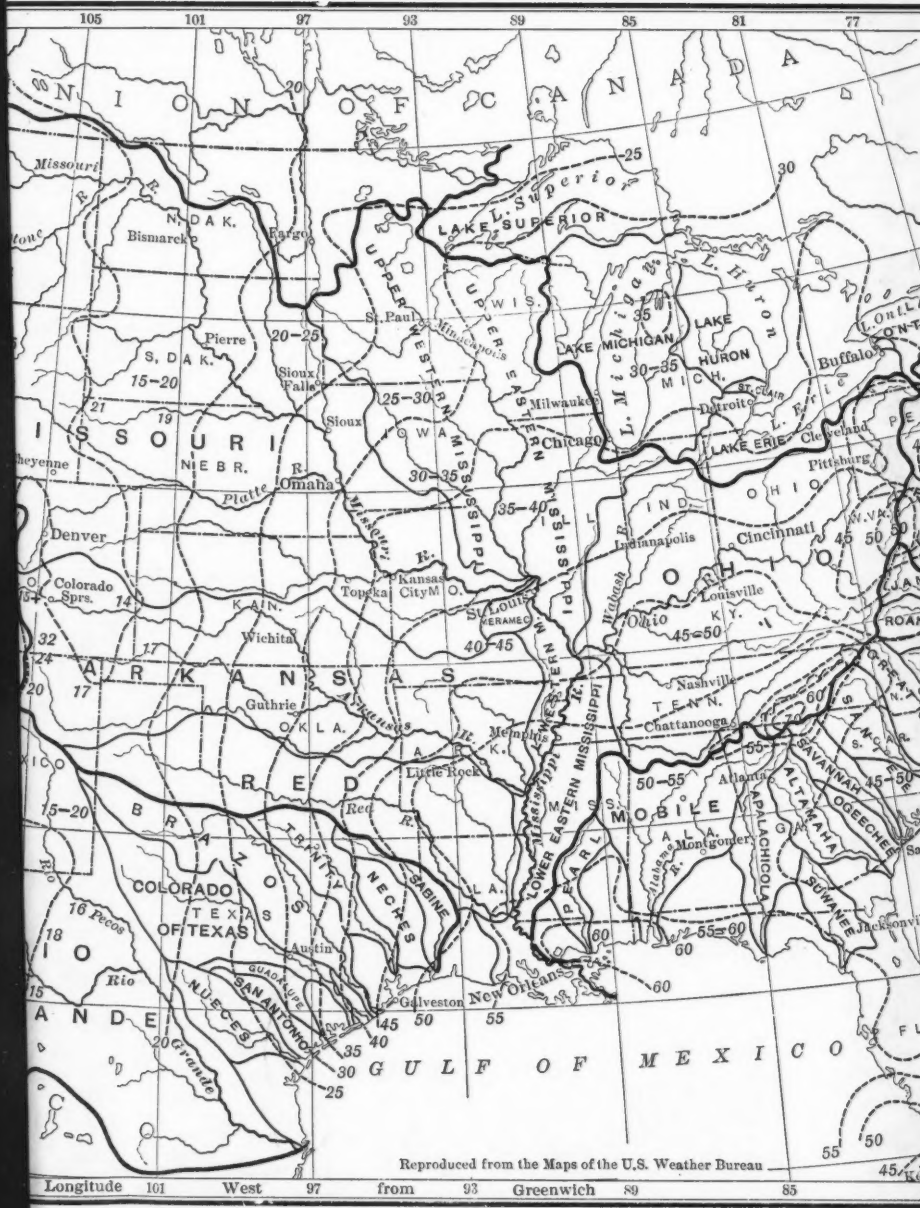
The run-off of a stream results from precipitation, and is the water left after evaporation, vegetation, seepage, etc., have been satisfied, plus the flow from ground-water. The seasonal distribution and rate of run-off depend mainly upon climate, topography, geology, vegetation, and ground, snow, or surface storage. Owing to lack of detailed information in regard to these regulating factors no attempt has been made to discuss the magnitude of their effects.

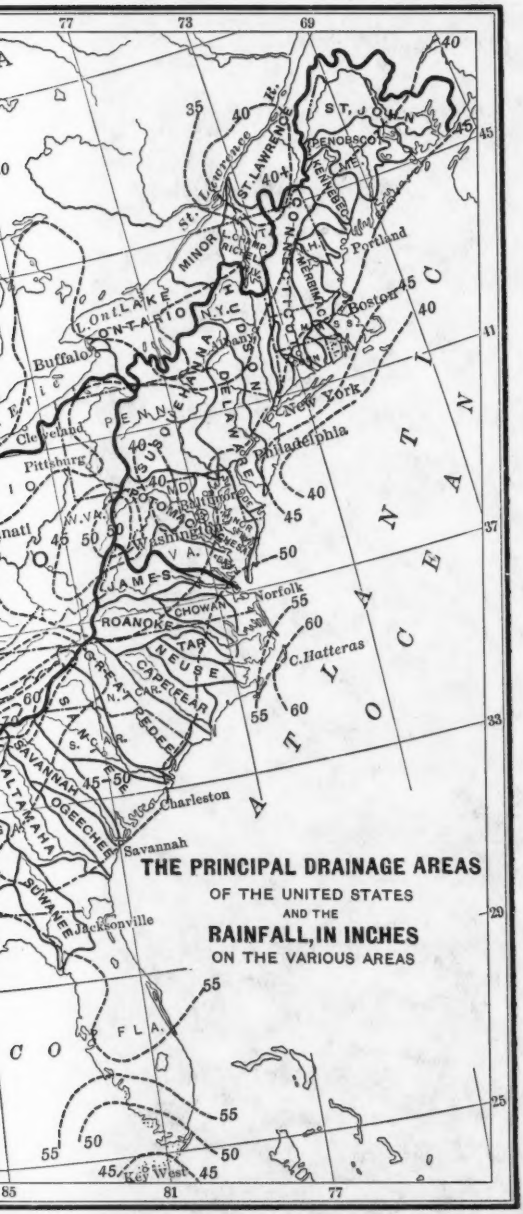
Comparison of Rainfall and Run-off.

In order to compare rainfall and run-off, the data have been expressed as "depth in inches," over the drainage basins in question, for uniform periods of time, usually the calendar month. This period, however, is too short for comparison, and leads to results which are apparently erroneous, because heavy precipitation may occur at the end of the month and not appear as run-off until the following month.

The year is a better period for the comparison of these quantities, but is not entirely satisfactory. The calendar year is unsatisfactory because the conditions of snow and ground storage are not the same at the end of each calendar year. A year beginning with October 1st makes a much better period, because on that day conditions are much more nearly uniform for successive years, as there is no snow storage, the ground-water will have been lowered to about the same level each year, and the ground storage is gen-


PRIMARY
DRAINAGE BASINS
NORTHERN ATLANTIC
SOUTHERN ATLANTIC
EASTERN GULF OF MEXICO
EASTERN MISSISSIPPI RIVER
ST. LAWRENCE RIVER
WESTERN MISSISSIPPI RIVER
WESTERN GULF OF MEXICO
COLORADO RIVER
THE GREAT BASIN
PACIFIC COAST
HUDSON BAY
The heavy lines indicate the principal Drainage Basins
The dotted lines and the figures indicate the Average Annual Precipitation, in inches, in the United States for 32 years, 1870 to 1901, as taken from Chart XII U.S. Weather Bureau, prepared by Alfred J. Henry, Professor of Meteorology.
THE PRINCIPAL
OF THE U
RAINFAL
ON THE V
Reproduced from the Maps of the U.S. Weather Bureau
Longitude West from Greenwich


105
101
97
93
89
85
81
77
UNION OF CANADA
Missouri R.
N. DAK.
Bismarck
Fargo
L. Superior
LAKE SUPERIOR
UPPER WEST MISSISSIPPI
WIS.
St. Paul
Minneapolis
L. Michigan
LAKE MICHIGAN
L. Huron
LAKE HURON
MICH.
Buffalo
Detroit
St. Clair
L. Erie
LAKE ERIE
Cleveland
Pittsburg
Pierre
S. DAK.
Sioux Falls
Sioux
IOWA
Milwaukee
Chicago
Cheyenne
NEBR.
Omaha
Platte R.
Missouri R.
Denver
Colorado Sprs.
Topeka
Kansas City
St. Louis
MISSISSIPPI R.
Indianapolis
Cincinnati
Louisville
Ohio R.
KY.
Wichita
KAN.
ARKANSAS
Guthrie
OKLA.
Arkansas R.
Memphis
Nashville
TENN.
Chattanooga
Red R.
Little Rock
LOWER MISSISSIPPI
Atlanta
Savannah
Mobile
Montgomery
ALA.
Apalachicola R.
Tombigbee R.
Pearl R.
COLORADO R. OF TEXAS
TEXAS
Austin
Rio Grande
Guadalupe R.
San Antonio
Nueces R.
Galveston
New Orleans
Sabine R.
LA.
GULF OF MEXICO
Reproduced from the Maps of the U.S. Weather Bureau
Longitude 101 West 97 from 93 Greenwich 89 85


77
73
69
40
35
45
41
37
33
29
25
85
81
77
ATLANTIC
St. Lawrence R.
ST. JOHN
PENOBSCOT
KENNEBEC
Portland
Boston
New York
Philadelphia
Buffalo
Cleveland
Pittsburg
L. Ontario
L. Erie
MINOR
Conv't Rich.
SUSQUEHANNA
POTOMAC
Washington
Baltimore
JAMES
Norfolk
ROANOKE
CHOWAN
TAR
NEUSE
CAPE FEAR
PEDEE
C. Hatteras
Charleston
Savannah
OGEECHEE
ALTAMAHA
SUWANEE
Jacksonville
FLA.
Key West
THE PRINCIPAL DRAINAGE AREAS
OF THE UNITED STATES
AND THE
RAINFALL, IN INCHES
ON THE VARIOUS AREAS

erally a minimum. This period, therefore, has been used in the following comparisons.

Areas Considered in the Comparisons.

The areas used in this discussion are indicated in Table 1 and shown on Plate LIII. These, with the exception of the Ohio above Wheeling, drain into the North Atlantic Ocean, and are representative of the New England States, New York, New Jersey, Pennsylvania, Maryland, Virginia and West Virginia.

The stations lowest down in the drainage basin, with the exception of the Roanoke drainage, have been designated "principal stations," and those in the upper portions of the area, "secondary stations."

TABLE 1.—List of Areas.

River.	Drainage above:	Drainage area, in square miles.	Length of records, in years.
Connecticut	Orford, N. H.	3 050	5
Housatonic	Gaylordsville, Conn.	1 020	5
Susquehanna	Harrisburg, Pa.	24 030	14
Susquehanna	Wilkes-Barre, Pa.*	9 810	6
Susquehanna	Williamsport, Pa.*	5 640	10
Ohio	Wheeling, W. Va.	23 820	21
Potomac	Point of Rocks, Md.	9 650	10
Shenandoah	Millville, W. Va.*	3 000	10
James	Cartersville, Va.	6 232	7
James	Buchanan, Va.*	2 060	10
James	Glasgow, Va.*	830	10
Appomattox	Mattoax, Va.*	745	5
Roanoke	Roanoke, Va.	390	9
Roanoke	Randolph, Va.*	3 080	5

* Secondary stations.

Description of Tables.

For comparative purposes, the following tables have been prepared:

Table 1.—List of areas.

Table 2.—Monthly rainfall, run-off, run-off in percentage of rainfall, and loss, over the area above each gauging station.

Table 3.—Monthly and yearly maximum, minimum and mean rainfall, run-off, run-off in percentage of rainfall, and loss for an average year over the area above each gauging station.

Table 4.—Yearly rainfall, run-off, run-off in percentage of rainfall, and loss, over the Susquehanna, Potomac, James and Roanoke basins.

Table 5.—Yearly rainfall, run-off, run-off in percentage of rainfall, and loss, over the area above each principal station.

Table 6.—The winter rainfall, run-off, run-off in percentage of rainfall, and loss, as indicated by the months of December, January, February, March and April; and the growing period of rainfall, run-off, run-off in percentage of rainfall, and loss, as indicated by the months of June, July and August.

General Discussion.

The drainage basins considered may be grouped as follows:

First.—High latitudes, as represented by the Connecticut above Orford, N. H.

Second.—Coast area, as represented by the Housatonic at Gaylordsville, Conn.

Third.—Medium latitude areas, as indicated by the Ohio at Wheeling, W. Va., and the Susquehanna at Harrisburg, Pa.

Fourth.—Mountain-surrounded area, as indicated by the Potomac above Point of Rocks, Md.

Fifth.—Southern areas, as shown by the James above Cartersville, Va., and the Roanoke above Roanoke, Va.

The general conditions of rainfall and run-off in the various basins are shown in Table 3, which gives the mean monthly and yearly values for those basins.

Neglecting the data for the Housatonic and Potomac drainages, which are in special classes, Table 3 shows a gradually increasing rainfall from the north to the south, varying from 36.76 in. in the Connecticut drainage to 42.68 in. in the Roanoke drainage. The large rainfall above Gaylordsville (47.86 in.) is explained by its proximity to the coast line, where the evaporation, and therefore the rainfall, is much greater than in the interior. The low rainfall in the Potomac basin (36.86 in.) may be accounted for by the topography of this basin, a large portion of which is surrounded by

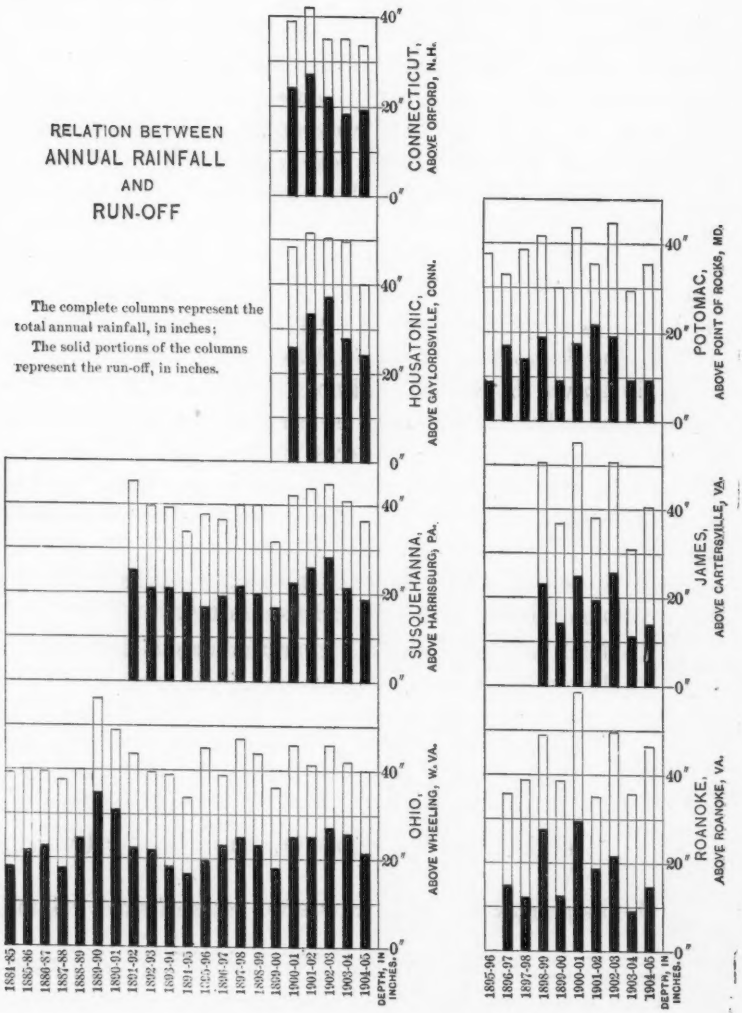

RELATION BETWEEN
ANNUAL RAINFALL
AND
RUN-OFF
The complete columns represent the total annual rainfall, in inches;
The solid portions of the columns represent the run-off, in inches.
CONNECTICUT, ABOVE ORFORD, N.H.
HOUSATONIC, ABOVE GAYLORDSVILLE, CONN.
SUSQUEHANNA, ABOVE HARRISBURG, PA.
OHIO, ABOVE WHEELING, W. VA.
POTOMAC, ABOVE POINT OF ROCKS, MD.
JAMES, ABOVE CARTERSVILLE, VA.
ROANOKE, ABOVE ROANOKE, VA.
40″
20″
0″
1884-85
1885-86
1886-87
1887-88
1888-89
1889-90
1890-91
1891-92
1892-93
1893-94
1894-95
1895-96
1896-97
1897-98
1898-99
1899-00
1900-01
1901-02
1902-03
1903-04
1904-05
1805-96
1806-97
1897-98
1898-99
1899-00
1900-01
1901-02
1902-03
1903-04
1904-05
DEPTH, IN INCHES.

FIG. 1.

high mountains which precipitate a large percentage of the moisture from the rain clouds, and thus reduce the rainfall beyond them.

The run-off is very consistent in the various groups, and decreases toward the south, although the rainfall increases. It is about 60% of the precipitation in the northern areas, 55% in the intermediate areas and 40% in the southern areas. This decrease in run-off is due to the increase in evaporation and the loss by vegetation, and shows that the climate and vegetation are probably the principal regulating factors in the relation between rainfall and run-off.

The actual loss of rainfall increases quite rapidly toward the south, ranging from 15.10 in. in the Connecticut drainage to 24.99 in. in the Roanoke drainage; the mean loss for frozen areas being 17.7 in. and for southern areas 24.13 in.

Table 4 gives the relative conditions in the various parts of the same drainage basins, and shows no perceptible difference in conditions between the various branches and the main stream. Unfortunately, data are not available for the extreme upper portions of the drainages, where it is probable that the run-off is somewhat greater than in the lower portions.

Table 5 and Fig. 1 show the relation between years of maximum and minimum rainfall on run-off and loss, as follows:

1.—High rainfall produces a correspondingly high run-off.

2.—Low rainfall produces a correspondingly low run-off.

3.—The run-off in percentage of rainfall varies with the rainfall. It is likely to be high during the years following high rainfall and low during the years following low rainfall.

4.—Small apparent loss occurs in years following low rainfall.

5.—Large apparent loss occurs after years of small rainfall.

These peculiarities are due mainly to the effect of ground storage, which is the most important factor governing run-off. At the ends of years of high precipitation the ground-water table will be high. Maximum ground storage exists at the end of maximum precipitation. The quantity of stored water carried into the following year will be large unless the rainfall has been small for the last

month or two, thus allowing the excess to drain off. Exceptions to the above are readily explained by extreme conditions during the latter months of the year, as shown in Table 2.

Table 6 shows the relation during the winter months, December to April, inclusive, and the summer or growing months, June to August, inclusive.

A study of these tables shows that in the northern area, where the ground is frozen, and where there is considerable snow during the winter months, the run-off very nearly equals the precipitation, being for the principal basins 92%, which shows that the evaporation and other loss, neglecting any gain or loss from ground storage, is very small during the winter period.

For the southern drainages, where the ground is frozen for a shorter period, and is rarely covered with a great depth of snow, the run-off during the winter months averages 63% for the principal basins.

That the climatic conditions are responsible for this change in the percentage of run-off between northern and southern areas, rather than geologic conditions or topography, is shown in the "percentage" column for the summer months, where the percentage of run-off varies between 20 and 32, having a mean of 27% for all the principal basins. This column shows no regular variation for the basins. It also shows that the evaporation and loss through evaporation is very nearly the same over the various areas considered, being about 9.5 in.

These relations for the winter months give a method of checking in a general way the winter run-off of streams in frozen areas, by comparison with the total precipitation for the winter months. Although this check is only approximate, it may be of considerable value, as the records of winter flow, as a rule, are very meager and unsatisfactory, owing to uncertainties in regard to ice conditions.

Table 2 gives the general conditions of rainfall and run-off for the various drainages for the individual months, and forms a basis for the other tables. The wide range of variations in this table shows the impossibility of estimating run-off from rainfall data. These variations, however, as a rule, may be explained by the variation of ground-water conditions, although the exact ground-water conditions may not be known. For example, the table for the

Potomac at Point of Rocks shows, in October, 1896, 162% of run-off, while the mean run-off for that month is 24% for all years. That this value is not in error is shown by the precipitation in September, which was 6.09 in., while the normal for September is only 2.65 in. This high precipitation in September evidently left an abnormally high ground-water at the end of the month, which maintained the flow during the following month. It will be noted, also, that the percentage of run-off for September was abnormally low, being only 4%, while the precipitation was abnormally high. In August there was an abnormally low precipitation and a correspondingly low ground-water, which was replenished by the heavy rainfall of September. This is only one of the many examples which can be pointed out in the tables for the various basins.

The principal reason, therefore, why rainfall data fail, as a basis for estimating run-off, is the lack of knowledge of ground-water conditions. If data in regard to these conditions were available, estimates from reliable rainfall data could no doubt be made more satisfactorily.

Special attention is called to Table 3, which shows the average conditions of run-off over the various areas. This table is of especially practical value to the engineer in showing him the conditions which may be expected within the limits of the areas discussed or for similar areas. It gives him not only the mean conditions, but also the absolute maximum and minimum during the years in question. The comparison of drainage areas in connection with such tables of run-off should be the only basis for estimating the run-off of streams on which no measurements of flow have been made.

TABLES
ACCOMPANYING PAPER ON RAINFALL AND STREAM FLOW.

RUN-OFF, IN PERCENTAGE OF PRECIPITATION.

1900-01.....	42	45	103	50	86	45	204	65	63	23	39	22	62	.....
1901-02.....	33	33	49	55	28	137	120	83	68	38	38	30	65	.....
1902-03.....	37	132	39	36	32	163	266	430	20	20	23	34	63	.....
1903-04.....	17	42	17	13	23	80	120	141	49	13	16	22	46	.....
1904-05.....	92	83	(35)	15	26	101	220	130	35	30	26	33	58	.....
Mean.....	41	57	46	33	34	114	170	104	45	25	28	28	59	.....
Maximum....	92	132	103	55	86	163	266	430	68	38	39	34	65	.....
Minimum....	17	33	17	13	23	45	120	65	20	13	16	22	46	.....

LOSS, IN INCHES.

1900-01.....	2.10	3.03	—0.06	0.99	0.10	1.92	—3.62	1.67	1.05	3.81	2.00	1.94	14.93	.....
1901-02.....	1.61	1.20	2.43	0.91	1.36	—1.77	—0.72	0.74	1.51	2.41	2.45	2.63	14.76	.....
1902-03.....	2.60	—0.41	2.08	1.88	2.15	—2.91	—2.27	—0.89	4.23	3.19	2.48	0.71	12.84	.....
1903-04.....	2.24	0.70	2.29	1.87	0.92	0.41	—0.70	1.39	1.08	3.27	3.62	4.50	18.81	.....
1904-05.....	0.18	0.18	(0.88)	1.97	0.75	—0.02	2.37	—0.67	2.59	3.55	3.39	3.74	14.17	.....
Mean.....	1.75	0.94	1.52	1.52	1.06	—0.47	—1.94	—0.11	2.09	3.25	2.79	2.70	15.10	.....
Maximum....	2.60	3.03	2.43	1.97	2.15	1.92	—0.70	1.67	4.23	3.81	3.62	3.74	18.81	.....
Minimum....	0.18	—0.41	—0.06	0.91	0.10	—2.91	—3.62	—1.39	1.05	2.41	2.00	0.71	12.84	.....

TABLE 2.—Monthly Rainfall, Run-off, Run-off in Percentage of Rainfall, and Loss. Connecticut River above Orford, N. H. Drainage Area, 3 300 Sq. Miles.

Precipitation.

Year.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Period.	No. Prec. Sta.
1900-01.....	3.63	5.54	1.73	1.99	0.71	3.52	3.48	4.78	2.81	4.97	3.29	2.48	38.93	10
1901-02.....	2.39	1.78	4.77	2.02	1.89	4.77	3.54	4.27	4.71	3.90	3.98	3.78	41.80	10
1902-03.....	4.12	1.27	3.39	2.94	3.18	4.65	1.37	0.27	5.27	4.00	3.22	1.08	34.76	10
1903-04.....	2.69	1.20	2.76	2.14	1.19	2.05	3.46	3.41	2.10	3.76	4.31	5.75	34.82	11
1904-05.....	2.12	1.05	1.36	2.32	1.01	2.20	1.98	2.23	4.00	5.06	4.59	5.56	33.48	8
Mean.....	2.99	2.17	2.80	2.28	1.60	3.44	2.77	2.99	3.78	4.34	3.88	3.73	36.76	.....
Maximum....	4.12	5.54	4.77	2.94	3.18	4.77	3.54	4.78	5.27	5.06	4.59	5.75	41.80	.....
Minimum.....	2.12	1.05	1.36	1.99	0.71	2.05	1.37	0.27	2.10	3.76	3.22	1.08	33.48	.....

Run-off.

1900-01.....	1.53	2.51	1.79	1.00	0.61	1.60	7.10	3.11	1.76	1.16	1.29	0.54	24.00	.....
1901-02.....	0.78	0.58	2.34	1.11	0.53	6.54	4.26	3.53	3.20	1.49	1.53	1.15	27.04	.....
1902-03.....	1.52	1.08	1.31	1.06	1.03	7.56	3.64	1.16	1.04	0.81	0.74	0.37	21.92	.....
1903-04.....	0.45	0.50	0.47	0.27	0.27	1.64	4.16	4.80	1.02	0.49	0.69	1.25	16.01	.....
1904-05.....	1.94	0.87	(0.48)	0.35	0.26	2.22	4.35	2.90	1.41	1.51	1.20	1.82	19.31	.....
Mean.....	1.24	1.23	1.28	0.76	0.54	3.91	4.70	3.10	1.69	1.09	1.09	1.03	21.66	.....
Maximum....	1.94	2.51	2.34	1.11	1.03	7.56	7.10	4.80	3.20	1.51	1.53	1.82	27.04	.....
Minimum	0.45	0.50	0.47	0.27	0.26	1.60	3.64	1.16	1.02	0.49	0.69	0.37	16.01	.....

Run-off, in Percentage of Precipitation.

1900-01.....	(13)	22	65	59	64	87	105	72	113	15	22	29	53	.....
1901-02.....	64	50	61	142	(39)	203	105	80	27	30	40	17	64	.....
1902-03..	51	175	67	92	(87)	151	170	99	59	61	31	80	73	.....
1903-04.....	50	78	67	(41)	(48)	(129)	109	77	48	37	20	23	56	.....
1904-05.....	58	69	(37)	(63)	(84)	(160)	187	118	20	11	18	46	60	.....
Mean.....	47	58	61	76	63	143	125	81	41	29	25	32	62	.....
Maximum....	64	175	67	149	(87)	203	187	118	113	61	40	80	73	.....
Minimum	(13)	22	(37)	(41)	(39)	87	105	72	20	11	18	17	53	.....

Loss, in Inches.

1900-01.....	(2.70)	3.33	0.96	0.67	0.27	0.66	—0.31	1.74	—0.25	4.25	5.71	2.83	22.56	.....
1901-02.....	0.98	1.20	2.63	—1.05	(2.36)	—4.46	—0.20	0.60	3.93	5.06	2.08	5.19	18.32	.....
1902-03.....	2.31	—0.67	1.93	0.26	(0.56)	—2.35	1.57	0.01	6.14	1.56	4.82	0.39	13.39	.....
1903-04.....	3.24	0.54	1.25	(1.99)	(1.38)	(—0.95)	—0.36	0.76	2.60	2.36	4.14	1.92	21.87	.....
1904-05.....	1.20	0.59	(1.73)	(1.82)	(0.20)	(—1.81)	—2.20	—0.22	—3.67	4.41	4.00	2.62	16.01	.....
Mean.....	2.09	1.00	1.70	0.73	0.95	—1.78	—0.92	0.57	3.22	3.53	4.15	3.19	18.43	... .
Maximum....	3.24	3.33	2.63	(1.99)	2.36	0.66	—0.20	1.74	6.14	5.06	5.71	5.19	22.56	... .
Minimum....	0.98	—0.67	0.96	—1.05	(0.20)	—4.46	—2.20	—0.22	—0.25	1.56	2.08	0.39	13.39	.....

TABLE 2—(*Continued*).

HOUSATONIC RIVER, ABOVE GAYLORDSVILLE, CONN. DRAINAGE AREA, 1 020 SQ. MILES.

PRECIPITATION.

Year.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Period	No. Prec. Sta.
1900-01.....	3.10	4.29	2.72	1.65	0.76	5.20	6.12	6.24	1.86	5.01	7.28	4.01	48.24	8
1901-02.....	2.74	2.40	6.76	2.16	3.89	4.31	3.79	3.06	5.41	7.25	3.45	6.27	51.49	7
1902-03.....	4.67	0.89	5.87	3.22	4.24	4.65	2.25	1.12	10.42	4.05	7.01	1.94	50.33	7
1903-04.....	6.49	2.46	3.79	3.35	2.65	3.29	3.84	3.26	5.02	3.72	5.19	6.42	49.48	7
1904-05.....	2.88	1.92	2.76	4.89	1.26	3.04	2.53	1.19	4.59	4.97	4.87	4.87	39.77	7
Mean.....	3.98	2.39	4.38	3.05	2.56	4.10	3.71	2.97	5.46	5.00	5.56	4.70	47.86	.....
Maximum....	6.49	4.29	6.76	4.89	4.24	5.20	6.12	6.24	10.42	7.25	7.28	6.42	51.49	.....
Minimum....	2.74	0.89	2.72	1.65	0.76	3.04	2.25	1.12	1.86	3.72	3.45	1.94	39.77	.....

RUN-OFF.

1900-01.....	(0.40)	0.96	1.76	0.98	0.49	4.54	6.43	4.50	2.11	0.76	1.51	1.18	25.68	.....
1901-02.....	1.76	1.20	4.13	3.21	(1.53)	8.77	3.99	2.46	1.48	2.19	1.37	1.08	33.17	.....
1902-03.....	2.36	1.56	3.94	2.96	(3.68)	7.00	3.82	1.11	4.28	2.49	2.19	1.55	36.94	.....
1903-04.....	3.25	1.92	2.54	(1.36)	(1.27)	(4.24)	4.20	2.50	2.42	1.36	1.05	1.50	27.61	.....
1904-05.....	1.68	1.33	(1.03)	(3.07)	(1.06)	(4.85)	4.73	1.41	0.92	0.56	0.87	2.25	23.76	.....
Mean.....	1.89	1.39	2.68	2.32	1.61	5.88	4.63	2.40	2.24	1.47	1.41	1.51	29.43	.....
Maximum....	3.25	1.92	4.13	3.21	(3.68)	8.77	6.43	4.50	4.28	2.49	2.19	2.25	36.94	.....
Minimum....	(0.40)	0.96	(1.03)	0.98	0.49	(4.24)	3.82	1.11	0.92	0.56	0.87	1.08	23.76	.....

Minimum .... 0.16 0.28 0.40 0.67 0.53 2.46 2.34 0.61 0.50 0.34 0.24 0.17 16.34 .....

Run-off, in Percentage of Precipitation.

1891-92.....	26	60	73	86	58	60	248	54	53	17	19	23	55	.....
1892-93.....	30	15	61	32	53	167	118	72	27	15	6	29	53	.....
1893-94.....	32	35	72	58	47	277	69	59	82	20	15	14	54	.....
1894-95.....	27	105	51	72	209	214	158	42	14	17	6	11	60	.....
1895-96.....	11	11	24	133	52	78	324	21	21	14	36	5	44	.....
1896-97.....	43	57	100	50	86	181	85	55	25	12	23	11	52	.....
1897-98.....	24	23	68	77	128	123	83	60	33	12	20	26	53	.....
1898-99.....	28	59	69	93	62	123	191	35	16	14	9	8	50	.....
1899-00.....	12	32	52	120	75	92	178	42	21	9	8	12	52	.....
1900-01.....	6	25	83	37	93	110	108	54	86	16	26	34	51	.....
1901-02.....	44	30	63	77	60	192	110	45	10	47	47	13	59	.....
1902-03.....	41	79	67	56	109	140	139	54	20	35	19	13	63	.....
1903-04.....	44	63	39	44	81	142	105	53	40	17	13	13	52	.....
1904-05.....	27	54	19	(63)	(41)	(175)	100	37	25	17	24	37	50	.....
Mean.....	30	41	59	71	74	134	124	52	31	20	18	20	55	.....
Maximum....	44	105	100	133	209	277	324	72	86	47	47	73	63	.....
Minimum	6	11	19	32	41	60	25	21	10	9	6	5	44	.....

Loss, in Inches.

1891-92.....	2.60	1.05	1.11	0.61	0.72	1.65	—2.21	2.74	2.68	3.84	3.70	1.78	20.27	.....
1892-93.....	0.66	2.95	0.50	1.56	2.14	—1.79	—0.74	1.68	2.29	2.77	4.57	2.13	18.72	.....
1893-94.....	1.87	1.31	0.75	0.95	1.56	—2.14	1.37	3.16	0.50	1.94	1.87	4.81	17.95	.....
1894-95.....	3.40	—0.11	1.59	0.92	—1.21	—2.04	—1.44	1.64	2.97	2.21	3.68	1.93	18.54	.....
1895-96.....	1.30	2.24	2.76	—0.62	2.13	0.89	—2.84	2.28	3.45	4.41	1.22	3.82	21.04	.....
1896-97.....	2.23	1.24	0.00	0.88	0.32	—1.01	0.44	2.14	2.42	3.99	2.38	2.59	17.62	.....
1897-98.....	0.91	3.42	1.03	0.84	—0.50	—0.79	0.50	1.90	1.84	2.74	5.10	1.52	18.51	.....
1898-99.....	4.16	1.32	0.76	0.16	1.22	—0.90	—1.48	2.26	2.72	2.38	3.73	3.40	19.73	.....
1899-00.....	1.48	1.83	1.41	—0.46	0.92	0.28	—1.18	1.28	2.34	3.34	2.80	1.24	15.28	.....
1900-01.....	3.14	3.34	0.36	1.14	0.06	—0.37	—0.37	2.61	0.40	3.31	4.64	1.99	20.25	.....
1901-02.....	0.80	1.61	2.10	0.53	1.37	—3.58	—0.29	0.89	5.57	3.99	1.47	3.58	18.04	.....
1902-03.....	2.42	0.27	1.50	1.42	—0.33	—1.82	—1.08	0.58	5.14	2.96	5.25	0.53	16.84	.....
1903-04.....	2.77	0.75	1.47	1.84	0.42	—1.46	—0.17	1.81	2.01	4.09	3.44	2.80	19.77	.....
1904-05.....	1.98	0.42	1.73	(1.26)	(0.76)	(—2.75)	0.00	1.55	3.81	3.88	3.58	3.01	18.23	.....
Mean.....	2.12	1.55	1.22	0.79	0.69	—1.13	—0.67	1.89	2.73	3.28	3.39	2.43	18.29	.....
Maximum....	4.16	3.42	2.76	1.84	2.14	1.65	1.37	3.16	5.57	4.41	5.25	4.81	21.04	.....
Minimum	0.66	—0.11	0.00	—0.62	—1.21	—3.58	—2.84	0.58	0.40	1.94	1.22	0.53	13.54	.....

TABLE 2—(*Continued*).

SUSQUEHANNA RIVER, ABOVE HARRISBURG, PA. DRAINAGE AREA, 28 030 SQ. MILES.

PRECIPITATION.

Year.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Period.	No. Prec. Sta.
1891-92.....	3.49	2.63	4.13	4.40	1.72	4.11	1.49	5.97	5.71	4.62	4.60	2.30	45.17	24
1892-93.....	0.95	3.45	1.28	2.30	4.55	2.68	4.06	6.05	3.15	3.26	4.84	3.00	39.57	24
1893-94.....	2.76	2.03	2.69	2.25	2.93	1.21	4.41	7.70	2.81	2.42	2.19	5.61	39.01	24
1894-95.....	4.64	2.04	3.28	3.32	1.11	1.78	2.50	2.84	3.47	2.66	3.93	2.17	38.74	24
1895-96.....	1.46	2.52	3.65	1.90	4.49	3.98	1.27	2.89	4.34	5.14	1.92	4.01	37.57	24
1896-97.....	3.88	2.89	1.04	1.77	2.33	3.22	3.03	4.72	3.24	4.53	3.11	2.90	36.66	24
1897-98.....	1.19	4.42	3.27	3.65	1.79	3.46	2.97	4.74	2.77	3.12	6.35	2.04	39.77	24
1898-99.....	5.74	3.23	2.43	2.29	3.22	3.94	1.63	3.48	3.25	2.76	4.08	3.70	39.75	24
1899-00.....	1.68	2.70	2.95	2.28	3.69	3.52	1.52	2.20	2.95	3.68	3.04	1.41	31.62	24
1900-01.....	3.35	4.43	2.12	1.81	0.93	3.52	4.46	5.68	2.96	3.96	6.24	3.01	42.47	24
1901-02.....	1.43	2.30	5.63	2.31	3.41	3.88	2.87	1.63	6.17	7.24	2.76	4.12	43.75	24
1902-03.....	4.13	1.24	4.56	3.23	3.71	4.58	2.76	1.27	6.44	4.52	6.48	1.95	44.87	24
1903-04.....	4.94	2.02	2.42	3.31	2.16	3.43	3.28	3.82	3.37	4.95	3.94	3.20	40.84	24
1904-05.....	2.71	0.92	2.13	3.41	1.29	3.65	2.34	2.45	5.06	4.66	4.68	3.19	36.49	22
Mean.....	3.02	2.63	2.97	2.73	2.67	3.35	2.76	3.96	3.98	4.11	4.16	3.04	39.38	.....
Maximum....	5.74	4.43	5.63	4.40	4.55	4.58	4.46	7.70	6.44	7.24	6.48	5.61	45.17	.....
Minimum	0.95	0.92	1.04	1.77	0.93	1.21	1.27	1.27	2.77	2.42	1.92	1.41	31.62	.....

RUN-OFF.

1891-92.....	0.89	1.58	3.02	3.79	1.00	2.46	3.70	3.23	3.03	0.78	0.90	0.52	24.90	... .
1892-93.....	0.29	0.50	0.78	0.74	2.41	4.47	4.80	4.37	0.86	0.49	0.27	0.87	20.85	.....
1893-94.....	0.89	0.72	1.94	1.30	1.37	3.35	3.04	4.54	2.31	0.48	0.32	0.80	21.06	.....
1894-95.....	1.24	2.15	1.69	2.40	2.32	3.82	3.94	1.20	0.50	0.45	0.25	0.24	20.20	.....
1895-96.....	0.16	0.28	0.89	2.52	2.36	3.09	4.11	0.61	0.89	0.73	0.70	0.19	16.53	.....
1896-97.....	1.65	1.65	1.04	0.89	2.01	4.23	2.59	2.58	0.82	0.54	0.73	0.31	19.04	.....
1897-98.....	0.28	1.00	2.24	2.81	2.29	4.25	2.47	2.84	0.93	0.38	1.25	0.52	21.26	.....
1898-99.....	1.58	1.91	1.67	2.13	2.00	4.84	3.11	1.22	0.53	0.38	0.35	0.30	20.02	.....
1899-00.....	0.20	0.87	1.54	2.74	2.77	3.24	2.70	0.92	0.61	0.34	0.24	0.17	16.34	.....
1900-01.....	0.21	1.09	1.76	0.67	0.87	3.89	4.83	3.07	2.56	0.65	1.60	1.02	22.22	.....
1901-02.....	0.63	0.69	3.53	1.78	2.04	7.46	3.16	0.74	0.60	3.25	1.29	0.54	25.71	.....
1902-03.....	1.71	0.97	3.06	1.81	4.04	6.40	3.84	0.69	1.30	1.56	1.23	1.42	28.03	.....
1903-04.....	2.17	1.27	0.95	1.47	1.74	4.89	3.45	2.01	1.36	0.86	0.50	0.40	21.07	.....
1904-05.....	0.73	0.50	0.40	(2.15)	(0.53)	(6.40)	2.34	0.90	1.25	0.78	1.10	1.18	18.26	.....
Mean.....	0.90	1.08	1.75	1.94	1.98	4.48	3.43	2.07	1.25	0.83	0.77	0.61	21.09	....
Maximum....	2.17	2.15	3.53	3.79	4.04	7.46	4.83	1.54	3.03	3.25	1.60	1.42	28.03	.....
Minimum	0.16	0.28	0.40	0.67	0.53	2.46	2.34	0.61	0.50	0.34	0.24	0.17	16.34	.....

RUN-OFF, IN PERCENTAGE OF PRECIPITATION.

1899-00.....	7	31	47	88	87	78	200	39	14	7	7	11	47	.....
1900-01.....	4	26	140	201	148	121	96	47	58	9	14	16	57	.....
1901-02.....	25	22	88	158	81	223	98	26	10	43	4	13	61	.....
1902-03.....	46	85	76	131	127	132	117	36	18	21	24	74	65	.....
1903-04.....	53	67	65	76	197	194	128	50	39	9	14	13	65	.....
1904-05.....	44	58	40	(81)	(47)	149	117	33	23	13	14	42	50	.....
Mean.....	35	40	77	112	111	148	117	41	24	20	15	25	58	.....
Maximum....	53	85	140	201	197	223	200	50	58	43	24	74	65	.....
Minimum....	4	22	40	76	(47)	78	96	26	10	7	4	11	47	.....

LOSS, IN INCHES.

1899-00.....	1.72	1.78	1.70	0.29	0.46	0.80	—1.50	1.20	2.54	3.85	2.53	1.25	16.62	.....
1900-01.....	3.45	3.46	—0.98	—1.72	—0.56	—0.72	0.21	2.87	1.32	3.67	5.10	2.46	18.61	.....
1901-02.....	1.27	2.08	0.67	—1.16	0.58	—4.33	0.05	1.61	5.30	4.45	2.76	3.76	17.04	.....
1902-03.....	2.07	0.17	0.97	—0.81	—0.78	—1.51	—0.39	0.71	5.21	3.47	4.98	0.43	14.52	.....
1903-04.....	2.82	0.74	0.85	0.83	—1.93	—2.99	—0.77	1.83	2.00	4.53	3.65	3.22	14.78	.....
1904-05.....	1.67	0.50	1.34	(0.62)	(0.65)	—1.60	—0.41	1.38	4.00	4.30	3.98	1.95	18.38	.....
Mean.....	2.17	1.45	0.77	0.32	—0.26	—1.73	—0.46	1.60	3.39	4.04	3.83	2.18	16.66	.....
Maximum....	3.45	3.46	1.70	0.83	(0.65)	0.80	0.21	2.87	5.30	4.53	5.10	3.76	18.61	.....
Minimum....	1.27	0.17	—0.98	—1.72	—1.93	—4.33	—1.50	0.71	1.32	3.47	2.53	0.43	14.52	.....

TABLE 2.—(*Continued*).

SUSQUEHANNA RIVER, ABOVE WILKES-BARRE, PA. DRAINAGE AREA, 9 810 SQ. MILES.

PRECIPITATION.

Year.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Period.	No. Prec. Sta.
1899-00.....	1.85	2.58	3.19	2.43	3.46	3.59	1.50	1.97	2.94	4.13	2.73	1.40	31.77	27
1900-01.....	3.58	4.70	2.29	1.69	1.17	3.36	4.67	5.39	3.11	4.03	5.96	2.94	42.89	27
1901-02.....	1.69	2.68	5.58	2.00	3.08	3.51	2.54	2.17	5.87	7.86	2.83	4.32	44.13	27
1902-03.....	3.83	1.13	4.04	2.64	2.93	4.77	2.30	1.11	6.38	4.39	6.51	1.67	41.70	27
1903-04.....	6.04	2.21	2.44	3.40	1.99	3.17	2.79	3.69	3.27	4.96	4.26	3.69	41.91	27
1904-05.....	3.00	1.18	2.24	3.25	1.22	3.23	2.38	2.07	5.21	4.94	4.62	3.39	36.73	24
Mean.....	3.33	2.41	3.30	2.57	2.30	3.60	2.70	2.73	4.46	5.05	4.49	2.90	39.85	.....
Maximum....	6.04	4.70	5.58	3.40	3.46	4.77	4.67	5.39	6.38	7.86	6.51	4.32	44.13	.....
Minimum....	1.69	1.13	2.24	1.69	1.17	3.17	1.50	1.11	2.94	4.03	2.73	1.40	31.77	.....

RUN-OFF.

1899-00.....	0.13	0.80	1.49	2.14	3.00	2.79	3.00	0.77	0.40	0.28	0.20	0.15	15.15	.....
1900-01.....	0.13	1.24	3.22	3.41	1.73	4.08	4.46	2.52	1.79	0.36	0.86	0.48	24.28	.....
1901-02.....	0.42	0.60	4.91	3.16	2.45	7.84	2.49	0.56	0.57	3.41	0.12	0.56	27.09	.....
1902-03.....	1.76	0.96	3.07	3.45	3.71	6.28	2.69	0.40	1.17	0.92	1.53	1.24	27.18	.....
1903-04.....	3.22	1.47	1.59	2.57	3.92	6.16	3.56	1.86	1.27	0.93	0.61	0.47	27.13	.....
1904-05.....	1.33	0.68	0.90	(2.63)	(0.57)	4.83	2.79	0.69	1.21	0.64	0.64	1.44	18.35	.....
Mean.....	1.16	0.96	2.53	2.89	2.56	5.33	3.17	1.13	1.07	1.01	0.66	0.72	23.19	.....
Maximum....	3.22	1.47	4.91	3.45	3.92	7.84	4.46	2.52	1.79	3.41	1.53	1.44	27.18	.....
Minimum....	0.13	0.60	0.90	2.14	(0.57)	2.79	2.49	0.40	0.40	0.28	0.12	0.15	15.15	.....

Run-off, in Percentage of Precipitation.

1895-96.....	12	12	25	77	52	74	276	38	33	22	58	7	42	.....
1896-97.....	64	33	102	50	59	139	85	65	19	13	23	10	55	.....
1897-98.....	23	27	66	87	146	123	86	50	25	14	17	25	57	.....
1898-99.....	24	63	55	99	50	144	168	41	15	13	7	10	50	.....
1899-00.....	11	41	48	116	70	83	208	45	27	12	82	17	52	.....
1900-01.....	10	42	85	58	43	126	116	58	66	16	22	39	55	.....
1901-02.....	49	29	76	59	49	200	123	51	12	54	37	9	63	.....
1902-03.....	23	34	62	66	123	163	109	34	26	38	23	56	63	.....
1903-04.....	39	68	30	56	86	147	106	69	38	27	9	9	61	.....
1904-05.....	21	60	15	(74)	(53)	(164)	90	49	37	26	25	26	53	.....
Mean.....	29	42	56	75	72	137	121	52	29	27	21	18	56	.....
Maximum....	64	68	102	116	146	200	276	69	66	54	82	56	63	.....
Minimum....	10	12	15	50	43	74	85	34	12	12	7	7	42	.....

Loss, in Inches.

1895-96.....	1.11	2.13	2.82	0.34	1.92	1.02	—2.54	1.27	3.00	4.47	0.96	4.39	20.89	.....
1896-97.....	1.54	1.02	—0.03	1.03	1.20	—1.46	0.47	1.55	2.58	4.58	2.54	3.08	18.05	.....
1897-98.....	0.90	3.58	1.20	0.46	—0.71	—1.21	0.43	2.11	2.52	2.50	4.56	0.93	17.27	.....
1898-99.....	4.71	1.00	1.26	0.04	1.74	—1.73	—1.25	2.17	3.06	2.41	3.91	3.14	20.46	.....
1899-00.....	1.66	1.63	2.06	—0.39	1.11	0.67	—1.44	1.21	2.14	3.21	2.97	0.87	15.70	.....
1900-01.....	3.34	2.59	0.30	0.77	0.72	—0.86	—0.76	2.26	1.25	3.19	5.18	1.95	19.93	.....
1901-02.....	0.46	2.05	1.34	1.01	1.62	—4.05	—0.74	0.94	5.05	3.47	1.72	3.34	16.21	.....
1902-03.....	2.46	0.94	1.56	1.06	—0.84	—2.79	—0.30	1.14	4.46	3.31	4.21	0.92	16.13	.....
1903-04.....	2.62	0.81	1.64	1.50	0.33	—2.33	—0.26	1.22	2.31	3.43	3.00	2.40	16.65	.....
1904-05.....	1.73	0.21	1.85	(0.88)	(0.49)	(—2.21)	0.26	1.29	2.73	3.30	3.65	2.11	16.29	.....
Mean.....	2.05	1.60	1.40	0.67	0.76	—1.50	—0.61	1.52	2.91	3.39	3.27	2.31	17.76	.....
Maximum....	4.71	3.58	2.82	1.50	1.92	1.02	0.47	2.26	5.05	4.58	5.18	4.39	20.89	.....
Minimum....	0.46	0.21	—0.03	—0.39	—0.84	—4.05	—2.54	0.94	1.25	2.41	0.96	0.87	15.70	.....

TABLE 2—(*Continued*).

SUSQUEHANNA RIVER, ABOVE WILLIAMSPORT, PA. DRAINAGE AREA, 5 640 SQ. MILES.

PRECIPITATION.

Year.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Period.	No. Prec. Sta.
1895-96.....	1.26	2.42	3.74	1.51	4.00	3.84	1.44	2.06	4.48	5.75	2.26	4.70	37.46	8
1896-97.....	4.22	2.75	1.26	2.04	2.95	3.77	3.21	4.47	3.18	5.28	3.30	3.37	39.79	8
1897-98.....	1.16	4.91	3.54	3.69	1.54	5.20	2.98	4.26	3.37	2.92	5.47	1.23	40.27	8
1898-99.....	6.22	2.68	2.81	2.49	3.46	3.89	1.85	3.70	3.60	2.77	4.18	3.50	41.15	8
1899-00.....	1.87	2.77	3.95	2.46	3.71	3.87	1.33	2.22	2.94	3.63	3.24	1.05	33.04	8
1900-01.....	3.71	4.43	2.05	1.83	1.28	3.42	4.69	5.41	3.69	3.79	6.62	3.19	44.11	8
1901-02.....	0.89	2.89	5.48	2.46	3.19	4.04	3.24	1.90	5.72	7.58	2.72	3.68	43.79	8
1902-03.....	3.18	1.43	4.12	3.09	3.68	4.41	3.23	1.74	6.03	5.30	5.44	2.08	43.73	8
1903-04.....	4.32	2.55	2.36	3.44	2.30	5.03	4.44	3.69	3.73	4.70	3.32	2.63	42.51	8
1904-05.....	2.20	0.54	2.18	3.33	1.05	3.46	2.50	2.52	4.36	4.45	4.87	2.84	34.30	5
Mean.....	2.90	2.74	3.15	2.63	2.72	4.09	2.89	3.20	4.11	4.62	4.14	2.83	40.02	.....
Maximum....	6.22	4.91	5.48	3.69	4.00	5.20	4.69	5.41	6.03	7.58	6.62	4.70	44.11	.....
Minimum	0.89	0.54	1.25	1.51	1.05	3.42	1.33	1.74	2.94	2.77	2.26	1.05	33.04	.....

RUN-OFF.

1895-96.....	0.15	0.29	0.92	1.17	2.08	2.82	3.98	0.79	1.48	1.28	1.30	0.31	16.57	.....
1896-97.....	2.68	1.73	1.28	1.01	1.75	5.23	2.74	2.92	0.60	0.70	0.76	0 34	21.74	.....
1897-98.....	0.26	1.33	2.34	3.23	2.25	6.41	2.55	2.15	0.85	0.42	0.91	0.30	23.00	.....
1898-99.....	1.51	1.68	1.55	2.45	1.72	5.62	3.10	1.53	0.54	0.36	0.27	0.36	20.69	.....
1899-00.....	0.21	1.14	1.89	2.85	2.60	3.20	2.77	1.01	0.80	0.42	0.27	0.18	17.34	.....
1900-01.....	0.37	1.84	1.75	1.06	0.56	4.28	5.45	3.15	2.44	0.60	1.44	1.24	24.18	.....
1901-02.....	0.43	0.84	4.14	1.45	1.57	8.09	3.98	0.96	0.67	4.11	1.00	0.34	27.58	.....
1902-03.....	0.72	0.49	2.56	2.03	4.52	7.30	3.53	0.60	1.57	1.99	1.23	1.16	27.60	.....
1903-04.....	1.70	1.74	0.72	1.94	1.97	7.38	4.70	2.47	1.42	1.27	0.32	0.23	25.86	.....
1904-05.....	0.47	0.33	0.33	(2.45)	(0.56)	(5.67)	2.24	1.23	1.63	1.15	1.22	0.73	18.01	.....
Mean.....	0.85	1.14	1.75	1.96	1.96	5.59	3.50	1.68	1.20	1.23	0.87	0.52	22.26	.....
Maximum....	2.68	1.84	4.14	3.23	4.52	8.09	5.45	3.15	2.44	4.11	1.44	1.24	27.60	.....
Minimum	0.15	0.29	0.33	1.01	0.56	2.82	2.24	0.60	0.54	0.36	0.27	0.18	16.57	.....

RUN-OFF.

1884-85.....	0.39	0.40	1.64	3.38	1.07	1.37	4.34	1.31	1.24	0.44	1.44	0.80	17.82	.....
1885-86.....	0.97	1.43	2.90	5.93	2.98	2.40	4.60	1.38	0.87	0.51	0.02	0.99	21.18	.....
1886-87.....	0.31	2.16	2.09	2.72	6.71	2.87	1.90	1.99	1.14	0.28	0.26	0.17	22.39	.....
1887-88.....	(0.16)	2.67	0.53	2.76	2.40	2.55	2.71	1.27	0.64	1.01	1.54	1.09	17.46	.....
1888-89.....	2.11	2.90	2.03	2.55	1.91	2.87	2.76	1.72	3.37	1.41	0.66	0.98	24.34	.....
1889-90.....	0.53	2.97	3.90	4.30	4.40	4.98	3.53	5.10	1.45	0.48	0.73	2.50	34.20	.....
1890-91.....	3.70	0.92	1.49	3.69	7.99	3.20	2.97	0.51	1.80	1.21	0.98	0.32	30.64	.....
1891-92.....	0.22	0.57	9.55	3.69	9.78	2.95	2.59	3.46	2.66	0.74	0.35	0.24	29.09	.....
1892-93.....	0.14	0.57	(1.24)	(7.26)	(5.42)	3.78	3.24	4.36	0.65	0.39	0.16	0.20	21.52	.....
1893-94.....	0.55	0.57	2.36	1.94	2.64	2.69	2.36	2.62	1.17	0.28	0.21	0.64	18.03	.....
1894-95.....	0.30	0.70	1.57	3.88	0.78	3.79	3.21	0.71	0.31	0.97	0.28	0.25	16.29	.....
1895-96.....	0.15	0.43	1.44	1.48	2.84	3.04	3.47	0.94	0.75	3.01	1.59	0.35	19.71	.....
1896-97.....	1.69	1.99	1.74	1.43	4.05	4.77	2.62	2.17	0.84	1.11	0.77	0.21	22.59	.....
1897-98.....	0.12	0.91	2.55	4.85	2.53	5.02	2.50	2.36	1.00	1.88	1.89	0.32	24.61	.....
1898-99.....	1.15	2.09	2.91	3.49	2.95	4.66	2.56	1.79	0.79	0.66	0.40	0.31	22.88	.....
1899-00.....	0.20	0.77	2.17	(8.04)	0.89	3.84	1.94	0.95	2.16	0.78	0.36	0.15	17.04	.....
1900-01.....	0.16	1.65	1.88	1.80	1.64	4.58	6.81	2.63	0.72	0.61	0.58	0.86	24.55	.....
1901-02.....	0.33	0.85	3.64	1.45	1.64	6.31	4.03	1.68	1.33	3.49	0.91	0.31	24.66	.....
1902-03.....	0.75	0.51	3.56	2.70	4.95	6.96	3.32	0.67	1.63	1.56	0.65	0.83	27.09	.....
1903-04.....	0.74	1.03	0.88	4.32	2.10	6.54	3.64	2.47	1.62	1.44	0.37	0.25	25.35	.....
1904-05.....	0.38	0.24	0.78	1.63	(2.51)	6.89	2.90	1.63	1.80	1.33	1.26	0.74	21.19	.....
Mean.....	0.72	1.21	1.99	2.78	3.12	4.07	3.20	1.94	1.30	1.06	0.76	0.53	22.68	.....
Maximum.....	3.70	2.97	3.64	4.30	7.29	6.89	6.81	5.10	3.37	3.49	1.88	2.50	34.20	.....
Minimum.....	0.12	0.24	0.53	(1.38)	0.78	1.37	1.90	0.51	0.31	0.28	0.16	0.15	16.29	.....

TABLE 2—(*Continued*).

OHIO RIVER, ABOVE WHEELING, W. VA. DRAINAGE AREA, 23 820 SQ. MILES.

PRECIPITATION.

Year.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Period.	No. Prec. Sta.
1884-85.....	2.53	1.76	3.67	4.27	1.97	1.40	2.78	3.81	4 19	3.59	6.88	2.27	39.12	15
1885-86.....	4.93	2.82	2.32	3.93	1.98	2.88	3.19	3.33	3.85	3.88	3.11	3.67	39.89	25
1886-87.....	1.21	4.91	2.98	2.14	5.54	1.94	3.11	2.94	4.41	3.18	3.14	2.84	39.34	25
1887-88.....	1.72	2.15	1.84	4.67	1.76	2.81	2.38	3.86	3.21	4.39	4.98	3.69	37.46	26
1888-89.....	3.84	3.35	2.06	3.09	1 94	2.17	3.64	4.03	5.01	4.27	2.31	3.81	39.52	27
1889-90.....	2.62	4.56	3.53	4.62	5.01	4.66	4.21	7.48	3.91	2.92	5.56	6.48	55.56	37
1890-91.....	6.78	2.60	3.73	3.04	6.01	3.70	2.22	2.81	5.15	6.23	3.91	2.45	48.63	40
1891-92.....	2.23	3.49	3.88	3.26	2.78	3.06	3.01	6.54	5.43	4.18	3.09	2.45	43.40	36
1892-93.....	1.36	3.12	2.07	2.76	5.83	1.97	5.24	5.31	3.36	3.08	3.44	1.91	39.40	42
1893-94.....	3.91	2.09	3.38	2.87	3.19	2.63	3.68	5.76	2.50	2.54	1.30	4.70	38.55	47
1894-95.....	2.53	2.54	3.82	4.22	1.19	2.34	2.68	2.18	3.12	3.38	3.41	2.06	33.47	51
1895-96.....	1.13	3.55	3.57	1.72	3.21	3.73	2.70	2.97	5.23	9.08	2.83	4.85	44.57	48
1896-97.....	2.35	3.01	1.95	2.16	3.66	3.85	3.31	3.61	3.43	6.29	3.15	1.67	38.44	52
1897-98	0.51	5.67	3.74	4.97	2.28	5.62	2.73	4.28	4.09	3.68	6.69	2.25	46.51	57
1898-99.....	4.66	3.31	2.73	3.19	2.97	4.61	1.89	4.78	4.03	4.60	2.38	4.11	43.26	54
1899-00.....	1.70	2.42	3.76	2.58	3.78	3.55	1.57	2.45	4.10	5.31	3.16	1.56	35.94	54
1900-01.....	2.78	5.09	1.93	2.45	1.20	3.69	6.50	5.25	4.51	3.15	4.91	3.75	45.21	57
1901-02.....	0.72	3.00	4.64	2.55	2.14	3.51	3.55	3.05	5.63	6.63	2.30	3.06	40.78	58
1902-03.....	3.16	1.99	5.07	3.02	4.81	4.38	3.45	2.59	5.80	4.94	4.35	1.64	45.20	60
1903-04.....	3.04	2.91	2.22	3.51	2.93	4.93	3.57	3.95	4.08	4.58	3.33	2.27	41.62	65
1904-05.....	2.15	0.65	2.84	3.02	1.87	3.70	3.07	3.91	5.72	5.77	4.26	2.89	39.91	62
Mean.....	2.66	3.09	3.13	3.24	3.19	3.39	3.28	4.04	4.32	4.55	3.74	3.07	41.71	.....
Maximum....	6.78	5.67	5.07	4.97	6.54	5.62	6.50	7.48	5.80	9.08	6.88	6.48	55.56	.....
Minimum	0.51	0.65	1.84	1.72	1.19	1.40	1.57	2.18	2.50	2.54	1.30	1.56	33.47	.....

LOSS, IN INCHES.

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TABLE 2—(*Continued*).

OHIO RIVER, ABOVE WHEELING, W. VA. DRAINAGE AREA, 23 820 SQ. MILES.

RUN-OFF, IN PERCENTAGE OF PRECIPITATION.

Year.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Period	No. Prec. Sta.
1884-85.....	15	23	45	79	54	98	156	34	30	12	21	35	46	.....
1885-86.....	20	51	95	75	151	83	144	41	23	13	20	8	53	.....
1886-87.....	26	44	70	127	103	148	58	64	26	9	8	6	57	.....
1887-88.....	(9)	13	29	59	136	91	114	33	20	37	31	28	47	.....
1888-89.....	55	80	99	83	98	132	76	43	67	33	29	7	62	.....
1889-90.....	20	64	93	93	88	107	84	68	37	16	13	39	62	.....
1890-91.....	55	114	40	129	121	89	134	18	35	19	25	21	63	.....
1891-92.....	10	26	66	81	100	96	86	53	49	18	11	10	51	.....
1892-93.....	10	18	(60)	(46)	(93)	191	62	82	19	13	5	15	55	.....
1893-94.....	14	27	70	68	83	102	64	45	47	11	16	14	47	.....
1894-95.....	12	30	41	92	66	116	120	33	10	13	7	12	49	.....
1895-96.....	13	12	40	86	88	82	129	32	19	33	56	7	44	.....
1896-97.....	72	43	89	66	111	124	79	60	22	18	24	13	59	.....
1897-98.....	24	16	68	98	126	89	92	55	21	10	28	14	53	.....
1898-99.....	25	63	85	(107)	85	101	135	57	25	14	17	8	53	.....
1899-00.....	12	32	58	118	78	108	124	27	19	15	11	10	49	.....
1900-01.....	6	32	97	73	69	124	105	50	48	19	12	23	54	.....
1901-02.....	46	28	78	57	77	180	114	35	13	53	40	7	60	.....
1902-03.....	24	26	70	89	103	143	96	26	23	32	15	51	60	.....
1903-04.....	24	35	37	123	72	133	94	63	40	31	11	11	61	.....
1904-05.....	18	37	27	54	(124)	183	72	42	31	23	30	26	53	.....
Mean.....	27	39	64	86	98	120	98	48	30	23	20	17	54	.....
Maximum....	72	114	99	129	151	191	156	82	67	53	56	39	63	.....
Minimum	6	12	27	(46)	54	82	58	18	10	9	5	6	44	.....

Run-off, in Percentage of Precipitation.

1895-96.....	12	11	10	32	33	(49)	(84)	(11)	13	19	24	4	22	.....
1896-97.....	162	26	76	33	78	104	55	57	28	16	17	17	51	.....
1897-98.....	17	6	24	46	84	41	78	45	27	9	38	22	35	.....
1898-99.....	25	41	63	98	70	106	99	27	18	13	10	7	44	.....
1899-00.....	11	22	25	47	42	64	80	23	23	10	11	8	30	.....
1900-01.....	8	15	42	30	85	48	76	50	48	34	16	28	39	.....
1901-02.....	90	22	54	75	90	149	104	37	11	13	13	8	61	.....
1902-03.....	10	13	50	58	69	89	89	25	32	33	16	24	43	.....
1903-04.....	15	27	45	42	163	64	35	33	24	12	12	8	32	.....
1904-05.....	8	19	10	33	35	97	44	18	15	18	17	20	26	.....
Mean.....	24	19	40	51	69	82	76	36	24	18	20	13	39	.....
Maximum....	162	41	76	98	163	149	104	57	48	34	38	28	61	.....
Minimum	8	6	10	30	33	41	35	(11)	11	9	10	4	22	.....

Loss, in Inches.

1895-96.....	1.05	1.22	2.32	1.34	2.32	(1.81)	(0.25)	(2.60)	4.38	4.68	1.28	5.84	29.09	.....
1896-97.....	—0.57	2.22	0.18	1.04	1.28	—0.09	1.03	2.03	1.74	3.44	2.44	1.33	16.07	.....
1897-98.....	1.19	3.86	2.44	2.03	0.17	2.60	0.52	2.60	1.33	2.92	4.34	1.03	25.03	.....
1898-99.....	4.78	1.42	1.08	0.05	1.41	—0.25	0.01	3.77	2.86	1.98	2.56	3.67	23.32	.....
1899-00.....	1.68	1.32	1.46	1.12	2.00	1.22	0.27	1.79	3.22	3.38	1.85	1.79	21.10	.....
1900-01.....	1.92	3.09	1.03	1.36	0.07	1.81	1.45	3.25	2.38	2.54	5.23	2.27	26.40	.....
1901-02.....	0.06	1.96	2.65	0.69	0.37	—2.15	—0.14	1.26	3.08	2.38	1.87	1.84	13.87	.....
1902-03.....	3.03	2.16	2.24	1.46	1.09	0.40	0.41	2.18	4.49	3.15	3.09	1.75	25.45	.....
1903-04.....	2.19	0.66	0.43	1.18	—0.75	0.74	1.60	2.31	3.61	4.00	2.03	2.07	20.07	.....
1904-05.....	1.52	0.64	2.26	2.09	1.12	0.09	0.96	2.51	4.47	5.41	3.38	1.49	25.94	.....
Mean.....	1.68	1.85	1.61	1.23	0.91	0.62	0.63	2.43	3.16	3.39	2.81	2.31	22.64	.....
Maximum....	4.78	3.86	2.65	2.09	2.32	2.60	1.60	3.77	4.49	5.41	5.23	5.84	29.09	.....
Minimum	—0.57	0.64	0.18	0.05	—0.75	—2.15	—0.14	1.26	1.33	1.98	1.27	1.03	13.87	.....

TABLE 2—(*Continued*).

POTOMAC RIVER, ABOVE POINT OF ROCKS, MD. DRAINAGE AREA, 9 650 SQ. MILES.

PRECIPITATION.

Year.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Period.	No. Prec. Sta.
1895-96.....	1.19	1.37	2.59	1.97	3.48	3.55	1.61	2.91	5.01	5.79	1.69	6.09	37.25	10
1896-97.....	0.92	3.02	0.74	1.55	5.88	2.40	2.28	4.77	2.43	4.08	2.93	1.60	32.60	12
1897-98.....	1.43	4.10	3.22	3.78	1.07	4.44	2.36	4.76	1.81	3.21	7.00	1.32	38.50	12
1898-99.....	6.41	2.41	2.91	2.54	4.44	3.96	1.37	5.15	3.47	2.28	2.84	3.94	41.72	13
1899-00.....	1.88	1.69	1.94	2.10	3.44	3.42	1.34	2.32	4.19	3.74	2.08	1.95	30.09	15
1900-01.....	2.08	3.62	1.77	1.95	0.46	3.46	6.05	6.47	4.56	3.82	6.23	3.15	43.63	15
1901-02.....	0.57	2.50	5.71	2.78	3.88	4.35	3.20	1.97	3.45	2.75	2.16	2.01	35.33	15
1902-03.....	3.36	2.49	4.50	3.51	3.49	3.59	3.75	2.92	6.57	4.67	3.67	2.29	44.81	14
1903-04.....	2.57	0.91	0.78	2.05	1.20	2.08	2.46	3.43	4.78	4.54	2.32	2.25	29.37	14
1904-05.....	1.66	0.79	2.52	3.12	1.73	2.89	1.72	3.05	5.23	6.63	4.08	1.86	35.28	13
Mean.....	2.21	2.29	2.67	2.53	2.91	3.42	2.61	3.77	4.15	4.15	3.50	2.65	36.86	.....
Maximum....	6.41	4.10	5.71	3.78	5.88	4.44	6.05	6.47	6.57	6.63	7.00	6.09	44.81	.....
Minimum	0.57	0.79	0.74	1.55	0.46	2.08	1.34	1.97	1.81	2.28	1.69	1.32	29.37	.....

RUN-OFF.

1895-96.....	0.14	0.15	0.27	0.63	1.16	(1.74)	(1.36)	(0.31)	0.63	1.11	0.41	0.25	8.16	.....
1896-97.....	1.49	0.80	0.56	0.51	4.60	2.49	1.25	2.74	0.69	0.64	0.49	0.27	16.53	.....
1897-98.....	0.24	0.24	0.78	1.75	0.90	1.84	1.84	2.16	0.48	0.29	2.66	0.29	13.47	.....
1898-99.....	1.63	0.99	1.83	2.49	3.03	4.21	1.36	1.38	0.61	0.30	0.28	0.27	18.38	.....
1899-00.....	0.20	0.37	0.48	0.98	1.44	2.20	1.07	0.53	0.97	0.36	0.23	0.16	8.99	.....
1900-01.....	0.16	0.53	0.74	0.59	0.39	1.65	4.60	3.22	2.18	1.28	1.00	0.88	17.22	.....
1901-02.....	0.51	0.54	3.06	2.09	3.51	6.50	3.34	0.71	0.37	0.37	0.29	0.17	21.46	.....
1962-03.....	0.33	0.33	2.26	2.05	2.40	3.19	3.34	0.74	2.08	1.52	0.58	0.54	19.36	.....
1903-04.....	0.38	0.25	0.35	0.87	1.95	1.34	0.86	1.12	1.17	0.54	0.29	0.18	9.30	.....
1904-05.....	0.14	0.15	0.26	1.03	0.61	2.80	0.76	0.54	0.76	1.22	0.70	0.37	9.34	.....
Mean.....	0.52	0.44	1.06	1.30	2.00	2.80	1.98	1.34	0.99	0.76	0.69	0.34	14.22	.....
Maximum....	1.63	0.99	3.06	2.49	4.60	6.50	4.60	3.22	2.18	1.52	2.66	0.88	21.46	.....
Minimum	0.14	0.15	0.26	0.51	0.39	1.34	0.76	(0.31)	0.37	0.29	0.23	0.16	8.16	.....

Run-off, in Percentage of Precipitation.

1895-96.....	20	15	9	38	35	35	85	36	13	18	14	5	21	.....
1896-97.....	623	16	383	33	(62)	81	53	47	19	13	27	25	51	.....
1897-98.....	10	12	18	31	75	23	61	42	21	11	41	26	30	.....
1898-99.....	31	59	55	78	(26)	(53)	106	20	29	14	10	10	34	.....
1899-00.....	13	64	40	44	36	61	55	27	14	14	17	8	29	.....
1900-01.....	11	18	47	30	139	34	77	58	41	39	33	25	40	.....
1901-02.....	99	25	51	74	67	148	113	38	18	19	18	10	58	.....
1902-03.....	11	13	54	64	54	73	81	38	36	43	17	35	44	.....
1903-04.....	23	44	38	(27)	(71)	(49)	31	31	16	15	17	12	23	.....
1904-05.....	17	21	12	28	27	69	38	14	17	19	19	18	23	.....
Mean.....	33	28	40	47	49	61	69	36	24	20	23	15	36	.....
Maximum....	623	64	383	78	139	148	113	65	41	43	41	41	58	.....
Minimum....	10	12	9	(27)	(26)	23	31	14	13	11	10	5	21	.....

Loss, in Inches.

1895-96.....	0.85	1.34	2.80	1.55	2.44	2.77	0.19	1.46	4.95	5.11	2.76	6.83	33.05	.....
1896-97.....	—2.51	3.48	—0.65	0.94	(2.36)	0.44	0.90	2.73	2.57	3.59	1.03	0.76	15.68	.....
1897-98.....	2.32	2.27	2.89	2.11	0.19	2.87	1.04	3.01	2.25	3.70	4.58	1.46	28.64	.....
1898-99.....	4.91	0.74	1.40	0.55	(3.67)	(2.40)	—0.07	3.97	1.49	2.17	3.56	3.41	28.20	.....
1899-00.....	2.04	0.29	0.80	1.43	2.40	1.46	0.85	1.77	5.14	3.28	1.61	2.88	23.90	.....
1900-01.....	2.83	2.40	0.97	1.61	—0.13	2.50	1.45	2.46	4.47	2.67	4.56	2.85	28.64	.. ..
1901-02.....	0.01	1.51	3.00	0.70	1.46	—1.73	—0.30	1.64	2.41	1.75	1.81	2.32	14.58	.....
1902-03.....	3.24	2.78	1.56	1.46	1.59	1.11	0.69	1.80	4.85	1.73	2.92	1.58	25.32	.....
1903-04.....	1.83	0.46	0.60	(1.32)	(0.36)	(1.06)	1.82	2.36	4.67	4.30	2.11	1.72	22.61	.....
1904-05.....	1.00	0.75	2.16	2.06	1.56	0.76	1.18	3.40	4.55	4.83	2.59	1.35	26.19	....
Mean.....	1.65	1.60	1.56	1.37	1.59	1.36	0.78	2.46	3.74	3.31	2.75	2.52	24.69	.....
Maximum....	4.91	3.48	3.00	2.11	(3.67)	(2.40)	1.82	3.97	5.14	5.11	4.58	6.83	33.05	.....
Minimum....	—2.51	0.29	—0.65	0.55	—0.13	—1.73	—0.30	1.46	1.49	1.73	1.03	0.76	14.58	.....

TABLE 2—(*Continued*).

SHENANDOAH RIVER, ABOVE MILLVILLE, W. VA. DRAINAGE AREA, 3 000 SQ. MILES.

PRECIPITATION.

Year.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Period.	No. Prec. Sta.
1895-96.....	1.06	1.57	3.09	2.49	3.78	4.25	1.24	2.28	5.71	6.21	3.20	7.22	42.10	4
1896-97.....	0.48	4.16	0.23	1.41	6.28	2.34	1.90	5.13	3.18	4.14	1.41	1.01	31.67	4
1897-98.....	2.59	2.59	3.51	3.05	0.75	3.73	2.66	5.21	2.86	4.18	7.73	1.97	40.83	5
1898-99.....	7.10	1.79	3.13	2.52	4.95	5.12	1.16	4.95	2.09	2.51	3.94	3.78	43.04	5
1899-00.....	2.34	0.81	1.34	2.57	3.73	3.72	1.89	2.42	5.98	3.76	1.93	3.14	33.63	5
1900-01.....	3.19	2.94	1.83	2.31	0.33	3.80	6.24	5.82	7.54	4.38	5.92	3.78	48.08	5
1901-02.....	0.69	2.01	6.12	2.69	4.46	3.61	2.23	2.64	2.93	2.17	2.22	2.59	34.36	4
1902-03.....	3.65	3.21	3.38	4.08	3.49	4.15	3.62	2.69	7.63	3.06	3.53	2.42	44.91	6
1903-04.....	2.39	0.82	0.96	1.80	1.26	2.08	2.64	3.43	5.57	5.04	2.53	1.95	30.47	7
1904-05.....	1.20	0.95	2.46	2.86	2.14	2.44	1.90	3.98	5.50	5.98	3.19	1.65	34.20	7
Mean.....	2.47	2.08	2.61	2.58	3.12	3.52	2.55	3.85	4.90	4.14	3.56	2.95	38.33	.....
Maximum....	7.10	4.16	6.12	4.08	6.28	5.12	6.24	5.82	7.63	6.21	7.73	7.22	48.08	.....
Minimum	0.48	0.81	0.23	1.41	0.33	2.08	1.16	2.28	2.09	2.17	1.41	1.01	30.47	.....

RUN-OFF.

1895-96.....	0.21	0.23	0.29	0.94	1.34	1.48	1.05	0.82	0.76	1.10	0.44	0.39	9.05	.....
1896-97.....	2.99	0.68	0.88	0.47	(3.92)	1.90	1.00	2.40	0.61	0.55	0.38	0.25	16.03	.....
1897-98.....	0.27	0.32	0.62	0.94	0.56	0.86	1.62	2.20	0.61	0.48	3.15	0.51	12.14	.....
1898-99.....	2.19	1.05	1.73	1.97	(1.28)	(2.72)	1.23	0.98	0.60	0.34	0.38	0.37	14.84	.....
1899-00.....	0.30	0.52	0.54	1.14	1.33	2.26	1.04	0.65	0.84	0.53	0.32	0.26	9.73	.....
1900-01.....	0.36	0.54	0.86	0.70	0.46	1.30	4.79	3.36	3.07	1.71	1.36	0.93	19.44	.....
1901-02.....	0.68	0.50	3.12	1.99	3.00	5.34	2.53	1.00	0.52	0.42	0.41	0.27	19.78	.....
1902-03.....	0.41	0.43	1.82	2.62	1.90	3.04	2.93	0.89	2.78	1.33	0.61	0.84	19.60	.....
1903-04.....	0.56	0.36	0.36	(0.48)	(0.90)	(1.02)	0.82	1.07	0.90	0.74	0.42	0.23	7.86	.....
1904-05.....	0.20	0.20	0.30	0.80	0.58	1.68	0.72	0.53	0.95	1.15	0.60	0.30	8.01	.....
Mean.....	0.82	0.48	1.05	1.21	1.53	2.16	1.77	1.39	1.16	0.83	0.81	0.43	13.64	.....
Maximum....	2.99	1.05	3.12	2.62	3.63	5.34	4.79	3.36	3.07	1.71	3.15	0.93	19.78	.....
Minimum	0.20	0.20	0.29	0.47	0.46	0.86	0.72	0.53	0.52	0.34	0.38	0.23	7.86	.....

Run-off, in Percentage of Precipitation.

1898-99.....	(28)	(58)	(47)	69	76	83	101	37	19	13	11	14	44	.....
1899-00.....	13	69	29	49	48	73	67	32	27	17	19	11	37	.....
1900-01.....	19	41	55	61	108	44	64	51	54	28	30	33	44	.....
1901-02.....	131	37	46	74	60	128	95	40	21	17	16	8	50	.....
1902-03.....	22	25	70	62	64	81	88	66	31	37	23	44	49	.....
1903-04.....	23	47	33	31	62	72	50	49	27	12	23	17	35	.....
1904-05.....	39	23	21	34	34	94	48	33	18	33	24	26	33	.....
Mean.....	25	36	46	56	60	81	71	43	29	24	23	21	42	.....
Maximum....	131	69	70	74	108	128	101	66	54	37	30	44	50	.....
Minimum	13	23	21	31	34	44	48	32	18	12	11	8	33	.....

Loss, in Inches.

1898-99.....	(6.01)	(0.88)	(2.02)	1.11	1.18	1.09	—0.02	2.05	2.87	2.53	4.75	3.54	28.03	.....
1899-00.....	2.26	0.29	1.34	1.70	2.31	1.02	0.95	1.98	3.89	2.46	1.24	3.53	22.97	.....
1900-01.....	3.04	1.85	1.24	1.04	—0.05	1.96	2.47	3.25	2.57	3.78	7.14	2.50	30.79	.....
1901-02.....	—0.17	0.90	3.90	0.88	1.93	—0.92	0.10	1.55	3.04	1.94	2.34	3.46	18.90	.....
1902-03.....	4.69	2.67	1.01	1.67	1.81	0.99	0.40	0.60	5.37	1.94	3.38	1.33	25.86	.....
1903-04.....	1.83	0.49	0.95	1.53	0.66	0.73	1.24	1.80	3.29	3.87	1.85	1.65	19.89	.....
1904-05.....	0.33	0.89	1.91	1.93	2.05	0.14	1.08	3.59	4.34	4.98	3.66	2.03	26.93	.....
Mean.....	2.57	1.14	1.77	1.40	1.41	0.72	0.89	2.12	3.63	3.07	3.48	2.57	24.77	.....
Maximum....	(6.01)	2.67	3.90	1.93	2.31	1.96	2.47	3.59	5.37	4.98	7.14	3.54	30.79	.....
Minimum	—0.17	0.29	0.95	0.88	—0.05	—0.92	—0.02	0.60	2.57	1.94	1.24	1.33	18.90	.....

TABLE 2—(*Continued*).

JAMES RIVER, ABOVE CARTERSVILLE, VA. DRAINAGE AREA, 6 230 SQ. MILES.

PRECIPITATION.

Year.	Oct.	Nov.	Dec	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Period.	No. Prec. Sta.
1898-99.....	8.35	2.09	3.82	3.61	4.92	6.38	1.72	3.40	3.55	2.98	5.35	4.11	50.23	6
1899-00.....	2.62	0.93	1.90	3.35	4.41	3.76	2.84	2.92	5.34	2.98	1.54	3.98	36.57	10
1900-01.....	3.75	3.12	2.78	2.67	0.59	3.48	6.92	6.70	5.62	5.23	10.22	3.75	54.83	10
1901-02.....	0.55	1.43	7.19	3.21	4.79	3.30	2.05	2.58	3.83	2.35	2.80	3.75	37.83	10
1902-03.....	6.05	3.57	3.41	4.43	5.08	5.29	3.42	1.78	7.73	3.06	4.38	2.39	50.59	8
1903-04.....	2.38	0.93	1.41	2.21	1.76	2.59	2.46	3.53	4.53	4.41	2.39	1.98	30.58	8
1904-05.....	0.54	1.15	2.41	2.94	3.11	2.34	2.09	5.33	5.29	7.47	4.79	2.75	40.21	8
Mean.....	3.46	1.89	3.28	3.20	3.52	3.88	3.07	3.75	5.13	4.06	4.50	3.24	42.98	.....
Maximum....	8.35	3.57	7.19	4.43	5.08	6.38	6.92	6.70	7.73	7.47	10.22	4.11	54.83	.....
Minimum	0.55	0.93	1.41	2.21	0.59	2.59	1.72	1.78	3.55	2.35	1.54	1.98	30.58	.....

RUN-OFF.

1898-99.....	(2.34)	(1.21)	(1.80)	2.50	3.74	5.29	1.74	1.35	0.68	0.38	0.60	0.57	22.20	.....
1899-00.....	0.36	0.64	0.56	1.65	2.10	2.74	1.89	0.94	1.45	0.52	0.30	0.45	13.60	.....
1900-01.....	0.71	1.27	1.54	1.63	0.64	1.52	4.45	3.45	3.05	1.45	3.08	1.25	24.04	.....
1901-02.....	0.72	0.53	3.29	2.38	2.86	4.22	1.95	1.03	0.79	0.41	0.46	0.29	18.93	.....
1902-03.....	1.35	0.90	2.40	2.76	3.27	4.30	3.02	1.18	2.36	1.12	1.00	1.06	24.73	.....
1903-04.....	0.55	0.44	0.46	0.68	1.10	1.86	1.22	1.73	1.24	0.54	0.54	0.33	10.69	.....
1904-05.....	0.21	0.26	0.50	1.01	1.06	2.20	1.01	1.74	0.95	2.49	1.13	0.72	13.28	.....
Mean.....	0.89	0.75	1.51	1.80	2.11	3.16	2.18	1.63	1.50	0.99	1.02	0.67	18.21	.....
Maximum....	(2.34)	1.27	3.29	2.76	3.74	5.29	4.45	3.45	3.05	1.45	3.08	1.25	24.73	.....
Minimum	0.21	0.26	0.46	0.68	0.64	1.52	1.01	0.94	0.68	0.38	0.30	0.29	10.69	.....

Run-off, in Percentage of Precipitation.

1895-96.....	27	17	(18)	(36)	44	50	80	19	14	25	16	16	28	.....
1896-97.....	14	26	34	28	92	80	67	50	17	16	16	22	50	.....
1897-98.....	92	75	16	40	72	40	78	41	14	9	39	13	30	.....
1898-99.....	29	53	44	75	76	102	92	40	18	8	5	9	45	.....
1899-00.....	9	30	16	50	48	96	61	22	24	12	13	8	34	.....
1900-01.....	25	59	67	64	105	58	76	56	32	31	31	26	49	.....
1901-02.....	69	32	63	69	69	172	123	26	14	17	19	80	58	.....
1902-03.....	8	14	63	55	72	84	83	79	24	38	15	33	46	.....
1903-04.....	21	23	23	28	54	92	71	57	32	11	15	14	38	.....
1904-05.....	41	19	11	24	16	129	40	35	21	36	18	14	33	.....
Mean.....	24	29	43	49	64	86	76	42	25	22	22	16	41	.....
Maximum....	92	75	67	75	105	172	123	79	32	38	39	80	58	.....
Minimum....	8	14	11	24	16	40	40	19	14	8	5	8	28	.....

Loss, in Inches.

1895-96.....	0.64	1.54	(3.07)	(1.41)	2.27	2.62	0.31	2.45	2.49	4.96	2.95	5.21	31.92	.....
1896-97.....	—0.20	3.83	—0.71	1.27	0.46	0.69	0.53	2.65	2.79	3.15	1.86	0.83	17.15	.....
1897-98.....	2.17	2.45	3.11	1.90	0.24	2.26	0.64	3.37	3.01	4.36	3.56	2.84	29.91	.....
1898-99.....	5.74	1.06	1.72	0.72	1.17	—0.11	0.14	2.78	2.82	2.66	4.08	3.33	26.66	.....
1899-00.....	1.80	0.50	1.81	1.35	2.41	0.15	0.92	2.40	3.91	3.25	1.48	3.76	23.74	.....
1900-01.....	2.85	1.71	0.86	0.91	—0.03	1.54	1.54	2.76	2.92	3.31	6.00	2.64	27.01	.....
1901-02.....	0.20	1.07	2.81	0.94	1.62	—2.27	—0.37	1.87	3.17	1.89	1.30	2.66	14.89	.....
1902-03.....	4.22	3.21	1.13	2.05	1.53	0.93	0.63	0.26	5.77	1.87	2.93	1.98	26.51	.....
1903-04.....	1.55	0.89	1.04	1.68	0.90	0.19	0.67	1.62	3.65	3.54	1.98	1.29	19.00	.....
1904-05.....	0.27	0.86	2.12	2.08	2.66	—0.69	1.30	4.10	3.52	5.46	2.51	2.22	26.41	.....
Mean.....	1.92	1.71	1.70	1.43	1.32	0.53	0.64	2.43	3.60	3.44	2.86	2.67	24.26	.....
Maximum....	2.85	3.83	(3.07)	2.05	2.66	2.62	1.54	4.10	5.77	5.46	6.00	5.21	31.92	.....
Minimum....	—0.20	0.50	—0.71	0.72	—0.03	—2.27	—0.37	0.26	2.79	1.87	1.30	0.83	14.89	.....

TABLE 2—(*Continued*).

JAMES RIVER, ABOVE BUCHANAN, VA. DRAINAGE AREA, 2 060 SQ. MILES.

PRECIPITATION.

Year.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Period.	No. Prec. Sta.
1895-96.....	0.88	1.85	3.76	2.20	4.06	5.26	1.57	3.03	5.19	6.60	3.52	6.20	44.12	6
1896-97.....	0.51	5.20	0.30	1.77	5.80	3.39	1.63	5.30	3.34	3.74	2.21	1.06	34.25	5
1897-98.....	2.39	2.65	3.70	3.18	0.86	3.79	2.94	5.76	3.50	4.81	5.83	3.28	42.69	7
1898-99.....	8.07	2.25	3.06	2.88	4.86	5.56	1.78	4.62	3.46	2.90	4.25	3.65	47.34	6
1899-00.....	1.98	0.71	2.16	2.70	4.61	3.52	2.37	3.10	5.14	3.69	1.71	4.09	35.78	5
1900-01.....	3.78	4.17	2.57	2.51	0.63	3.71	6.52	6.31	6.07	4.77	8.71	3.56	53.31	7
1901-02.....	0.64	1.37	7.63	3.03	5.26	3.16	1.64	2.53	3.69	2.27	1.61	2.89	35.72	5
1902-03.....	4.56	3.74	3.04	4.56	5.41	5.66	3.62	1.25	7.57	3.00	3.47	2.93	48.81	4
1903-04.....	1.95	1.16	1.36	2.34	1.94	2.39	2.31	3.81	5.40	3.96	2.33	1.50	30.45	5
1904-05.....	0.46	1.07	2.38	2.73	3.17	2.39	2.18	6.28	4.45	8.48	3.07	2.58	38.24	5
Mean.....	2.52	2.42	3.00	2.79	3.66	3.88	2.66	4.20	4.78	4.42	3.67	3.17	41.17	.....
Maximum...	8.07	5.20	7.63	4.56	5.80	5.66	6.52	6.31	7.57	8.48	8.71	6.20	53.31	.....
Minimum....	0.46	0.71	0.30	1.77	0.63	2.39	1.57	1.25	3.34	2.27	1.61	1.06	30.45	.....

RUN-OFF.

1895-96.....	0.24	0.31	(0.69)	(0.79)	1.79	2.64	1.26	0.58	0.70	1.64	0.57	0.99	12.20	.....
1896-97.....	0.71	1.37	1.01	0.50	5.34	2.70	1.10	2.65	6.55	0.59	0.35	0.23	17.10	.....
1897-98.....	0.22	0.20	0.59	1.28	0.62	1.53	2.30	2.39	0.49	0.45	2.27	0.44	12.78	.....
1898-99.....	2.33	1.19	1.34	2.16	3.69	5.67	1.64	1.84	0.64	0.24	0.22	0.32	21.28	.....
1899-00.....	0.18	0.21	0.35	1.35	2.20	3.37	1.45	0.70	1.23	0.44	0.23	0.33	12.04	.....
1900-01.....	0.93	2.46	1.71	1.60	0.66	2.17	4.98	3.55	3.15	1.46	2.71	0.92	26.30	.....
1901-02.....	0.44	0.30	4.82	2.09	3.64	5.43	2.01	0.66	0.52	0.38	0.31	0.23	20.83	.....
1902-03.....	0.34	0.53	1.91	2.51	3.88	4.73	2.99	0.99	1.80	1.13	0.54	0.95	22.30	.....
1903-04.....	0.40	0.27	0.32	0.66	1.04	2.20	1.64	2.19	1.75	0.42	0.35	0.21	11.45	.....
1904-05.....	0.19	0.21	0.26	0.65	0.51	3.08	0.88	2.18	0.93	3.02	0.56	0.36	12.83	.....
Mean.....	0.60	0.71	1.30	1.36	2.34	3.35	2.02	1.77	1.17	0.96	0.81	0.50	16.91	.....
Maximum...	2.33	2.46	4.82	2.51	5.34	5.67	4.98	3.55	3.15	3.02	2.71	0.99	26.30	.....
Minimum....	0.18	0.20	0.26	0.42	0.51	1.53	0.88	0.58	0.49	0.24	0.22	0.21	11.45	.....

Run-off, in Percentage of Precipitation.

1895-96.....	28	15	13	34	52	51	122	32	13	33	16	32	33	.....
1896-97.....	381	32	653	35	73	76	87	55	19	14	12	32	50	.....
1897-98.....	11	14	20	39	80	37	74	48	29	16	43	12	33	.....
1898-99.....	28	64	51	67	55	70	64	18	9	10	6	9	33	.....
1899-00.....	10	42	18	48	51	92	47	23	24	16	21	8	42	.....
1900-01.....	14	34	53	41	88	62	59	45	52	22	33	29	41	.....
1901-02.....	92	27	59	73	68	127	128	18	15	12	16	6	53	.....
1902-03.....	8	11	51	62	71	75	75	69	21	27	14	32	41	.....
1903-04.....	24	31	34	43	168	60	37	38	24	16	20	13	39	.....
1904-05.....	36	21	12	32	23	100	43	32	23	46	17	19	34	.....
Mean.....	26	28	42	49	66	70	66	37	24	24	22	19	39	.....
Maximum....	381	64	653	73	168	127	128	69	52	33	33	32	53	.....
Minimum....	8	11	12	34	51	37	37	18	9	10	6	6	33	.....

Loss, in Inches.

1895-96.....	0.66	1.60	3.08	1.88	2.02	2.55	−0.26	2.12	4.25	4.18	3.82	4.56	30.46	.....
1896-97.....	−0.90	3.60	−0.94	1.17	1.49	0.74	0.18	2.31	2.60	3.17	2.37	0.50	16.29	.....
1897-98.....	2.32	1.99	2.84	1.54	0.13	2.20	0.71	2.54	1.92	3.69	3.16	2.93	25.97	.....
1898-99.....	6.22	0.69	1.35	1.02	2.30	1.92	0.57	3.47	3.14	2.16	4.49	3.27	30.60	.....
1899-00.....	2.10	0.42	1.50	1.54	2.27	0.26	1.45	2.72	4.31	2.60	1.15	4.02	24.34	.....
1900-01.....	3.56	1.97	1.06	1.51	0.06	1.49	2.88	3.41	2.72	4.18	4.98	2.33	30.15	.....
1901-02.....	0.05	1.07	3.10	0.86	1.52	−0.86	−0.45	2.62	2.69	1.91	1.35	2.87	16.73	.....
1902-03.....	3.25	3.40	1.52	1.70	1.61	1.28	0.93	0.41	6.87	2.95	3.48	2.38	29.78	.....
1903-04.....	1.80	0.92	0.90	1.17	−1.34	1.12	2.08	2.61	4.05	2.84	2.01	1.59	19.70	.....
1904-05.....	0.39	0.92	2.25	2.10	2.23	−0.01	1.04	3.05	3.77	3.35	2.94	1.67	23.70	.....
Mean.....	1.94	1.66	1.67	1.45	1.23	1.07	0.91	2.53	3.63	3.10	2.97	2.61	24.77	.....
Maximum....	6.22	3.60	3.10	1.88	2.30	2.55	2.88	3.47	6.87	4.18	4.98	4.56	30.46	.....
Minimum....	−0.90	0.42	−0.94	0.86	−1.34	−0.86	−0.45	0.41	1.92	1.91	1.15	0.50	16.29	.....

TABLE 2—(*Continued*).

NORTH (OF JAMES) RIVER, ABOVE GLASGOW, VA. DRAINAGE AREA, 830 SQ. MILES.

PRECIPITATION.

Year.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Period.	No. Prec. Sta.
1895-96.....	0.92	1.88	3.54	2.86	4.17	5.18	1.19	3.10	4.89	6.22	4.57	6.70	45.22	2
1896-97.....	0.32	5.27	0.17	1.80	5.48	3.06	1.37	5.14	3.22	3.68	2.68	0.73	32.92	3
1897-98.....	2.60	2.31	3.56	2.53	0.66	3.48	2.71	4.92	2.72	4.41	5.54	3.84	38.78	4
1898-99.....	8.70	1.92	2.74	3.07	5.13	6.36	1.60	4.24	3.44	2.40	4.77	3.58	47.95	2
1899-00.....	2.34	0.73	1.83	2.95	4.59	3.17	2.74	3.54	5.67	3.08	1.46	4.39	36.49	4
1900-01.....	4.12	3.00	2.28	2.55	0.49	3.93	7.08	6.18	5.72	5.36	7.47	3.30	51.48	4
1901-02.....	0.60	1.46	7.60	3.17	4.81	3.14	1.59	3.20	3.15	2.18	1.60	3.04	35.54	4
1902-03.....	3.54	3.84	3.10	4.49	5.46	5.14	3.63	1.33	8.71	4.02	4.08	3.48	50.77	3
1903-04.....	2.38	1.33	1.36	2.07	1.97	2.81	3.22	4.24	5.36	3.40	2.52	1.82	32.48	3
1904-05.....	0.61	1.16	2.56	3.08	2.91	2.67	1.84	4.50	4.89	6.17	3.54	2.07	36.00	3
Mean.....	2.61	2.29	2.87	2.86	3.57	3.89	2.70	4.04	4.78	4.09	3.82	3.24	40.76	.....
Maximum....	8.70	5.27	7.60	4.49	5.48	6.36	7.08	6.18	8.71	6.22	7.47	6.70	51.48	.....
Minimum	0.32	0.73	0.17	1.80	0.49	2.67	1.19	1.33	2.72	2.18	1.46	0.73	32.48	.....

RUN-OFF.

1895-96.....	0.26	0.28	0.46	0.98	2.15	2.63	1.45	0.98	0.64	2.04	0.75	2.14	14.76	.....
1896-97.....	1.22	1.67	1.11	0.63	3.99	2.32	1.19	2.83	0.62	0.51	0.31	0.23	16.63	.....
1897-98.....	0.28	0.32	0.72	0.99	0.53	1.28	2.00	2.38	0.80	0.72	2.38	0.41	12.81	.....
1898-99.....	2.48	1.23	1.39	2.05	2.83	4.44	1.03	0.77	0.30	0.24	0.28	0.31	17.35	.....
1899-00.....	0.24	0.31	0.33	1.41	2.32	2.91	1.29	0.82	1.36	0.48	0.31	0.37	12.15	.....
1900-01.....	0.55	1.03	1.22	1.04	0.43	2.44	4.20	2.77	3.00	1.18	2.49	0.97	21.33	.....
1901-02.....	0.55	0.39	4.50	2.31	3.29	4.00	2.04	0.58	0.46	0.27	0.25	0.17	18.81	.....
1902-03.....	0.29	0.44	1.58	2.79	3.85	3.86	2.70	0.92	1.84	1.07	0.55	1.10	20.99	.....
1903-04.....	0.58	0.41	0.46	0.90	3.31	1.69	1.19	1.63	1.31	0.56	0.51	0.23	12.78	.....
1904-05.....	0.22	0.24	0.31	0.98	0.68	2.68	0.80	1.45	1.12	2.82	0.60	0.40	12.30	.....
Mean.....	0.67	0.63	1.21	1.41	2.34	2.82	1.79	1.51	1.15	0.99	0.84	0.63	15.99	.....
Maximum....	2.48	1.67	4.50	2.79	3.99	4.44	4.20	2.83	3.00	2.82	2.49	2.14	21.33	.....
Minimum	0.22	0.24	0.31	0.63	0.43	1.28	0.80	0.58	0.30	0.24	0.25	0.17	12.15	.....

RUN-OFF, IN PERCENTAGE OF PRECIPITATION.

1900-01.....	11	13	17	44	48	26	58	44	22	24	31	18	32	.....
1901-02.....	160	47	29	77	88	76	65	54	20	22	19	14	46	.....
1902-03.....	19	33	71	57	69	67	113	47	41	32	18	45	48	.....
1903-04.....	22	47	45	30	82	64	79	24	19	10	20	49	35	.....
1904-05.....	51	21	54	48	64	70	42	25	13	9	14	28	30	.....
Mean.....	23	29	39	53	74	62	69	36	23	18	23	29	39	.....
Maximum....	160	47	71	77	88	76	113	54	41	32	31	49	48	.....
Minimum	11	13	17	30	48	26	42	24	13	9	14	14	30	.....

LOSS, IN INCHES.

1900-01.....	2.09	2.20	2.80	1.89	0.49	2.27	2.51	4.07	2.49	2.78	9.05	3.46	36.10	.....
1901-02.....	—0.21	0.56	5.77	0.76	0.46	0.98	0.82	0.79	4.04	1.51	2.88	2.26	20.62	.....
1902-03.....	6.16	2.67	1.06	2.09	1.62	1.95	—0.41	1.05	2.19	2.83	5.07	1.27	27.55	.....
1903-04.....	2.03	0.69	1.03	1.39	0.40	0.96	0.23	2.91	3.38	3.47	2.17	1.22	19.88	.....
1904-05.....	0.29	1.69	0.86	1.48	1.13	0.71	1.61	3.76	3.35	6.42	4.93	2.11	28.34	.....
Mean.....	2.07	1.56	2.30	1.52	0.82	1.38	0.95	2.52	3.09	3.40	4.82	2.07	26.50	.....
Maximum....	6.16	2.67	5.77	2.09	1.62	2.27	2.51	4.07	4.04	6.42	9.05	3.46	36.10	.....
Minimum	—0.21	0.56	0.86	0.76	0.40	0.71	—0.41	0.79	2.19	1.51	2.17	1.22	19.88	.....

TABLE 2—(*Continued*).

APPOMATTOX RIVER, ABOVE MATTOAX, VA. DRAINAGE AREA, 745 SQ. MILES.

PRECIPITATION.

Year.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Period.	No. Prec. Sta.
1900-01.....	2.36	2.53	3.38	3.34	0.94	3.05	5.99	7.26	3.20	3.67	13.06	4.20	52.98	3
1901-02.....	0.35	1.06	8.08	3.37	3.96	4.09	2.33	1.72	5.04	1.94	3.56	2.63	38.13	2
1902-03.....	7.60	3.99	3.60	4.82	5.22	5.96	3.26	1.97	3.70	4.14	6.15	2.29	52.70	1
1903-04.....	2.61	1.31	1.88	2.00	2.27	2.68	1.08	3.83	4.18	3.86	2.70	2.40	30.80	2
1904-05.....	0.59	2.13	1.88	2.86	3.15	2.37	2.77	5.00	3.83	7.05	5.72	2.98	40.28	2
Mean.....	2.70	2.20	3.76	3.28	3.11	3.63	3.09	3.96	3.99	4.13	6.24	2.89	42.98	.....
Maximum....	7.60	3.99	8.08	4.82	5.22	5.96	5.99	7.26	5.04	7.05	13.06	4.20	52.98	.....
Minimum....	0.35	1.06	1.88	2.00	0.94	2.37	1.08	1.72	3.20	1.94	2.70	2.29	30.80	.....

RUN-OFF.

1900-01.....	0.27	0.33	0.58	1.45	0.45	0.78	3.48	3.19	0.71	0.89	4.01	0.74	16.88	.....
1901-02.....	0.56	0.50	2.31	2.61	3.50	3.11	1.51	0.93	1.00	0.43	0.68	0.37	17.51	.....
1902-03.....	1.44	1.32	2.54	2.73	3.60	4.01	3.67	0.92	1.51	1.31	1.08	1.02	25.15	.....
1903-04.....	0.58	0.62	0.85	0.61	1.87	1.72	0.85	0.92	0.80	0.39	0.53	1.18	10.92	.....
1904-05.....	0.30	0.44	1.02	1.38	2.02	1.66	1.16	1.24	0.48	0.63	0.79	0.82	11.94	.....
Mean.....	0.63	0.64	1.46	1.75	2.29	2.26	2.13	1.44	0.90	0.73	1.42	0.83	16.48	.....
Maximum....	1.44	1.32	2.54	2.73	3.60	4.01	3.67	3.19	1.51	1.31	4.01	1.18	25.15	.....
Minimum....	0.27	0.33	0.58	0.61	0.45	0.78	0.85	0.92	0.48	0.39	0.53	0.37	10.92	.....

Run-off, in Percentage of Precipitation.

1896-97.....	44	27	92	13	57	63	69	62	57	13	17	26	42	.....
1897-98.....	19	21	10	47	152	27	(57)	36	28	14	47	29	32	.....
1898-99.....	48	77	75	90	96	115	49	35	16	12	8	9	56	.....
1899-00.....	16	23	27	46	45	58	81	27	21	21	17	7	32	.....
1900-01.....	27	44	52	63	93	48	75	58	36	48	53	37	51	.....
1901-02.....	92	51	57	78	76	102	89	41	14	13	27	9	54	.....
1902-03.....	9	15	7	(46)	(55)	70	87	125	22	24	21	34	43	.....
1903-04.....	29	25	30	22	33	48	25	25	15	15	41	31	25	.....
1904-05.....	208	17	11	19	15	82	49	33	34	30	28	42	31	.....
Mean.....	31	31	39	50	60	72	66	43	24	24	35	24	41	.....
Maximum...	208	77	92	90	152	115	89	125	57	48	53	37	56	.....
Minimum....	9	15	7	13	15	27	25	25	14	12	8	7	25	.....

Loss, in Inches.

1896-97.....	0.53	3.25	0.04	1.42	3.04	1.38	0.51	1.42	0.81	4.12	2.36	1.41	20.29	.....
1897-98.....	3.12	0.89	3.33	1.55	—0.32	2.53	(0.84)	3.92	2.04	3.72	1.89	2.65	26.16	.....
1898-99.....	3.26	0.43	0.64	0.39	0.20	—1.00	1.44	2.11	4.23	2.77	3.41	3.65	21.53	.....
1899-00.....	1.33	1.25	1.41	1.42	2.12	2.05	0.46	2.60	4.63	2.44	1.24	4.81	25.76	.....
1900-01.....	3.13	2.17	1.60	0.87	0.05	1.68	1.60	3.10	4.52	2.71	4.99	2.22	28.64	.....
1901-02.....	0.07	0.51	3.22	0.64	(1.23	—0.06	0.20	1.09	3.30	2.81	0.72	2.18	15.91	.....
1902-03.....	3.96	3.91	0.75	(2.22)	2.41)	1.92	0.51	—0.23	4.43	2.81	2.86	3.03	28.58	.....
1903-04.....	1.53	1.44	0.87	1.63	1.26	1.26	1.70	2.57	6.95	4.32	1.96	0.84	26.33	.....
1904-05.....	—0.14	1.55	2.81	2.61	4.10	0.41	0.93	4.91	1.75	8.10	2.81	1.87	31.71	.....
Mean.....	1.86	1.71	1.63	1.42	1.57	1.13	0.94	2.39	3.63	3.75	2.47	2.53	24.99	.....
Maximum...	3.96	3.91	3.33	2.61	4.10	2.53	1.70	4.91	6.95	8.10	4.99	4.81	31.71	.....
Minimum....	—0.14	0.43	0.04	0.39	—0.32	—1.00	0.20	—0.23	0.81	2.44	0.72	0.84	15.91	.....

TABLE 2—(*Continued*)

ROANOKE RIVER, ABOVE ROANOKE, VA. DRAINAGE AREA, 390 SQ. MILES.

PRECIPITATION.

Year.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Period.	No. Prec. Sta.
1896-97.....	0.95	4.47	0.50	1.64	7.10	3.74	1.67	3.71	1.90	4.72	2.83	1.96	35.19	3
1897-98.....	3.86	1.13	3.72	2.90	0.62	3.47	1.96	6.14	2.82	4.32	3.59	3.75	38.28	3
1898-99.....	6.32	1.89	2.60	3.73	5.83	6.49	2.82	3.23	5.03	3.16	3.72	4.03	48.85	3
1899-00.....	1.59	1.62	1.92	2.62	3.84	4.91	2.44	3.55	5.85	3.08	1.50	5.16	38.08	3
1900-01.....	4.26	3.88	3.31	2.36	0.71	3.26	6.50	7.46	7.06	5.26	10.72	3.52	58.30	3
1901-02.....	0.86	1.04	7.45	2.96	5.05	3.04	1.76	1.85	3.84	3.24	0.98	2.40	34.47	2
1902-03.....	4.36	4.60	2.43	4.08	5.40	6.46	3.94	0.93	5.65	3.72	3.60	4.56	49.73	1
1903-04.....	2.14	1.91	1.25	2.08	1.90	2.44	2.28	3.44	8.14	5.10	3.31	1.22	35.21	2
1904-05.....	0.13	1.87	3.16	3.24	4.80	2.25	1.84	7.80	2.66	11.64	3.92	3.22	46.08	1
Mean.....	2.71	2.49	2.92	2.85	3.92	4.01	2.80	4.18	4.77	4.91	3.80	3.32	42.68	.....
Maximum....	6.32	4.60	7.45	4.08	7.10	6.49	6.50	7.46	8.14	11.64	10.72	5.16	58.30	.....
Minimum	0.13	1.04	0.50	1.64	0.62	2.44	1.67	0.93	1.90	3.08	0.98	1.22	34.47	.....

RUN-OFF.

1896-97..	0.42	1.22	0.46	0.22	4.06	2.36	1.16	2.29	1.09	0.60	0.47	0.55	14.90	.....
1897-98.....	0.74	0.24	0.39	1.35	0.94	0.94	(1.12)	2.22	0.78	0.60	1.70	1.10	12.12	....
1898-99.....	3.06	1.46	1.96	3.34	5.63	7.49	1.38	1.12	0.80	0.39	0.31	0.38	27.32	.....
1899-00.....	0.26	0.37	0.51	1.20	1.72	2.86	1.98	0.95	1.22	0.64	0.26	0.35	12.32	.....
1900-01..	1.13	1.71	1.71	1.49	0.66	1.58	4.90	4.36	2.54	2.55	5.73	1.30	29.66	.....
1901-02.....	0.79	0.53	4.23	2.32	3.82	3.10	1.56	0.76	0.54	0.43	0.26	0.22	18.56	.....
1902-03.....	0.40	0.69	1.68	(1.86)	(2.99)	4.54	3.43	1.16	1.22	0.91	0.74	1.52	21.15	.....
1903-04.....	0.61	0.47	0.38	0.45	0.64	1.18	0.58	0.87	1.19	0.78	1.35	0.38	8.88	.....
1904-05.....	0.27	0.32	0.35	0.63	0.70	1.84	0.91	2.39	0.91	3.54	1.11	1.35	14.32	.....
Mean.....	0.85	0.78	1.29	1.43	2.35	2.88	1.89	1.79	1.14	1.16	1.33	0.80	17.69	.....
Maximum....	3.06	1.71	4.23	3.34	5.63	7.49	4.90	4.36	2.54	3.54	5.73	1.53	29.66	.....
Minimum	0.26	0.24	0.35	0.22	0.64	0.94	0.58	0.76	0.54	0.39	0.26	0.22	8.88	.....

RUN-OFF, IN PERCENTAGE OF PRECIPITATION.

1900-01.....	25	34	44	71	116	44	58	50	38	46	44	44	47	.....
1901-02.....	180	89	46	63	67	103	87	54	33	30	34	25	57	.....
1902-03.....	33	30	53	55	51	64	58	66	28	28	24	40	44	.....
1903-04.....	35	39	41	36	58	41	55	32	21	16	30	35	32	.....
1904-05.....	45	17	24	36	(31)	76	31	23	37	28	27	37	32	.....
Mean.....	40	36	43	53	56	65	56	41	30	29	35	37	43	.....
Maximum....	180	89	53	71	116	103	87	66	38	46	44	44	57	.....
Minimum	25	17	24	36	(31)	41	31	23	21	16	24	25	32	.....

LOSS, IN INCHES.

1900-01.....	2.84	2.08	1.92	0.82	—0.14	1.91	2.55	3.17	2.78	2.75	6.27	1.84	28.79	.....
1901-02.....	—0.56	0.14	4.23	1.18	1.75	—0.09	0.24	1.02	2.65	1.87	1.58	1.99	16.00	.....
1902-03.....	3.72	2.13	1.76	2.06	2.73	2.36	1.86	0.65	3.86	2.38	3.24	1.74	28.49	.....
1903-04.....	1.53	1.06	1.05	1.41	0.93	1.47	0.67	2.32	4.75	4.04	2.57	1.21	23.01	.....
1904-05.....	0.35	1.63	2.23	1.86	(2.65)	0.56	2.03	4.95	1.78	6.30	3.08	1.96	29.38	.....
Mean.....	0.58	1.41	2.24	1.47	1.58	1.24	1.47	2.42	3.16	3.47	3.35	1.75	25.14	.....
Maximum....	3.72	2.13	4.23	2.06	2.73	2.36	2.55	4.95	4.75	6.30	6.27	1.99	29.38	.....
Minimum	—0.56	0.14	1.05	0.82	—0.14	—0.09	0.24	0.65	1.78	1.87	1.58	1.21	16.00	.....

TABLE 2—(*Continued*).

ROANOKE RIVER, ABOVE RANDOLPH, VA. DRAINAGE AREA, 3 080 SQ. MILES.

PRECIPITATION.

Year.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Period.	No. Prec. Sta.
1900-01.....	3.81	3.15	3.40	2.83	0.88	3.41	6.04	6.33	4.51	5.09	11.21	3.29	53.95	6
1901-02.....	0.70	1.22	7.84	3.20	5.24	3.14	1.84	2.24	3.98	2.68	2.40	2.66	37.14	4
1902-03.....	5.54	3.05	3.77	4.35	5.63	6.49	4.41	1.92	5.37	3.29	4.25	2.92	50.99	4
1903-04.....	2.35	1.73	1.78	2.19	2.21	2.51	1.48	3.42	5.98	4.83	3.66	1.86	34.00	7
1904-05.....	0.65	1.95	2.94	2.90	3.85	2.29	2.96	6.44	2.83	8.73	4.23	3.12	42.89	7
Mean.....	2.61	2.22	3.95	3.10	3.56	3.57	3.35	4.07	4.53	4.92	5.15	2.77	43.80	.....
Maximum....	5.54	3.15	7.84	4.35	5.63	6.49	6.04	6.33	5.98	5.09	11.21	3.29	53.95	.....
Minimum....	0.65	1.22	1.78	2.19	0.88	2.29	1.48	1.92	2.83	2.68	2.40	1.86	34.00	.....

RUN-OFF.

1900-01.....	0.97	1.07	1.48	2.01	1.02	1.50	3.49	3.16	1.73	2.34	4.94	1.45	25.16	.....
1901-02.....	1.26	1.08	3.61	2.02	3.49	3.23	1.60	1.22	1.33	0.81	0.82	0.67	21.14	.....
1902-03.....	1.82	0.92	2.01	2.29	2.90	4.13	2.55	1.27	1.51	0.91	1.01	1.18	22.50	.....
1903-04.....	0.82	0.67	0.73	0.78	1.28	1.04	0.81	1.10	1.23	0.79	1.09	0.65	10.99	.....
1904-05.....	0.30	0.32	0.71	1.04	(1.20)	1.73	0.93	1.49	1.05	2.43	1.15	1.16	13.51	.....
Mean.....	1.03	0.81	1.71	1.63	1.98	2.33	1.88	1.65	1.37	1.45	1.80	1.02	18.66	.....
Maximum....	1.82	1.08	3.61	2.29	3.49	4.13	3.49	3.16	1.73	2.43	4.94	1.45	25.16	.....
Minimum....	0.30	0.32	0.71	0.78	1.02	1.04	0.81	1.10	1.05	0.79	0.82	0.65	10.99	.....

TABLE 3.—MONTHLY AND YEARLY MAXIMUM, MINIMUM AND MEAN LOSS, FOR AN

Note:—M. = Mean;

PRECIPITATION, IN INCHES.

Drainage.	OCTOBER.		NOVEMBER.		DECEMBER.		JANUARY.		FEBRUARY.		MARCH.	
	M.	R.	M.	R.	M.	R.	M.	R.	M.	R.	M.	R.
Connecticut, above Orford; 3 300 sq. miles....	2.99	4.12 2.12	2.17	5.54 1.05	2.80	4.77 1.36	2.28	2.94 1.99	1.60	3.18 0.71	3.44	4.77 2.05
Housatonic, above Gaylordsville; 1020 sq. miles	3.98	6.49 2.74	2.39	4.29 0.89	4.38	6.76 2.72	3.05	4.89 1.65	2.56	4.24 0.76	4.10	5.20 3.04
Susquehanna, above Harrisburg; 24 030 sq. miles.	3.02	5.74 0.95	2.63	4.43 0.92	2.97	5.63 1.04	2.73	4.40 1.77	2.67	4.55 0.93	3.35	4.58 1.21
Susquehanna, above Wilkes-Barre; 9 810 sq. miles.....	3.33	6.04 1.69	2.41	4.70 1.13	3.30	5.58 2.24	2.57	3.40 1.69	2.30	3.46 1.17	3.60	4.77 3.17
Susquehanna, above Williamsport; 5 640 sq. miles	2.90	6.22 0.89	2.74	4.91 0.54	3.15	5.48 1.25	2.63	3.69 1.51	2.72	4.00 1.05	4.09	5.20 3.42
Ohio, above Wheeling; 23 820 sq. miles.....	2.66	6.78 0.51	3.09	5.67 0.65	3.13	5.07 1.84	3.24	4.97 1.72	3.19	6.54 1.19	3.39	5.62 1.40
Potomac, above Point of Rocks; 9 650 sq. miles..	2.21	6.41 0.57	2.29	4.10 0.79	2.67	5.71 0.74	2.53	3.78 1.55	2.91	5.88 0.46	3.42	4.44 2.08
Shenandoah, above Millville; 3 000 sq. miles....	2.47	7.10 0.48	2.08	4.16 0.81	2.61	5.12 0.23	2.58	4.08 1.41	3.12	6.28 0.33	3.52	5.12 2.08
James, above Cartersville; 6 230 sq. miles.....	3.46	8.35 0.55	1.89	3.57 0.93	3.28	7.19 1.41	3.20	4.43 2.21	3.52	5.08 0.59	3.88	6.38 2.59
James, above Buchanan; 2 060 sq. miles.....	2.52	8.07 0.46	2.42	5.20 0.71	3.00	7.63 0.30	2.79	4.56 1.77	3.66	5.80 0.63	3.88	5.66 2.39
James, above Glasgow; 830 sq. miles.....	2.61	8.70 0.32	2.29	5.27 0.73	2.87	7.60 0.17	2.86	4.49 1.80	3.57	5.48 0.49	3.89	6.36 2.67
Appomattox, above Mattoax; 745 sq. miles.....	2.70	7.60 0.35	2.20	3.99 1.06	3.76	8.08 1.88	3.28	4.82 2.00	3.11	5.22 0.94	3.63	5.96 2.37
Roanoke, above Roanoke; 390 sq. miles.....	2.71	6.32 0.13	2.49	4.60 1.04	2.92	7.45 0.50	2.85	4.08 1.64	3.92	7.10 0.62	4.01	6.49 2.44
Roanoke, above Randolph; 3 080 sq. miles...	2.61	5.54 0.65	2.22	3.15 1.22	3.95	7.84 1.78	3.10	4.35 2.19	3.56	5.63 0.88	3.57	6.49 2.29

RUN-OFF, IN INCHES.

Drainage.	OCTOBER.		NOVEMBER		DECEMBER.		JANUARY.		FEBRUARY.		MARCH.	
	M.	R.	M.	R.	M.	R.	M.	R.	M.	R.	M.	R.
Connecticut, above Orford.....	1.24	1.94 0.45	1.23	2.51 0.50	1.28	2.34 0.47	0.76	1.11 0.27	0.54	1.03 0.26	3.91	7.56 1.60
Housatonic, above Gaylordsville	1.89	3.25 (0.40)	1.39	1.92 0.96	2.68	4.13 (1.03)	2.32	3.21 0.98	1.61	(3.68) 0.49	5.88	8.77 (4.24)
Susquehanna, above Harrisburg	0.90	2.17 0.16	1.08	2.18 0.28	1.75	3.53 0.40	1.94	3.79 0.67	1.98	4.04 0.53	4.48	7.46 2.46
Susquehanna, above Wilkes-Barre.....	1.16	3.22 0.13	0.96	1.47 0.60	2.53	4.91 0.90	2.89	3.45 2.14	2.56	3.92 1.57	5.33	7.84 2.79
Susquehanna, above Williamsport.....	0.85	2.68 0.15	1.14	1.84 0.29	1.75	4.14 0.33	1.96	3.23 1.01	1.96	4.52 0.56	5.59	8.09 2.82
Ohio, above Wheeling....	0.72	3.70 0.12	1.21	2.97 0.24	1.99	3.64 0.53	2.78	4.30 1.28	3.12	7.29 0.78	4.07	6.89 1.37
Potomac, above Point of Rocks.....	0.52	1.63 0.14	0.44	0.99 0.15	1.06	3.06 0.26	1.30	2.49 0.51	2.00	4.60 0.39	2.80	6.50 1.34
Shenandoah, above Millville.....	0.82	2.99 0.20	0.48	1.05 0.20	1.05	3.12 0.29	1.21	2.62 0.47	1.53	3.63 0.46	2.16	5.34 0.86
James, above Cartersville.....	0.89	2.34 0.21	0.75	1.27 0.26	1.51	3.29 0.46	1.80	2.76 0.68	2.11	3.74 0.64	3.16	5.29 1.52
James, above Buchanan.	0.60	2.33 0.18	0.71	2.46 0.20	1.30	4.82 0.26	1.36	2.51 0.42	2.34	5.34 0.51	3.35	5.67 1.53
James, above Glasgow...	0.67	2.48 0.22	0.63	1.67 0.24	1.21	4.50 0.31	1.41	2.79 0.63	2.34	3.99 0.43	2.82	4.44 1.28
Appomattox, above Mattoax.....	0.63	1.44 0.27	0.64	1.32 0.33	1.46	2.54 0.58	1.75	2.73 0.61	2.29	3.60 0.45	2.26	4.01 0.78
Roanoke, above Roanoke.	0.85	3.06 0.26	0.78	1.71 0.24	1.29	4.23 0.35	1.43	3.34 0.22	2.34	5.63 0.64	2.88	7.49 0.94
Roanoke, above Randolph.....	1.03	1.22 0.30	0.81	1.08 0.32	1.71	3.61 0.71	1.63	2.29 0.78	1.98	3.49 1.02	2.33	4.13 1.04

RAINFALL, RUN-OFF, RUN-OFF IN PERCENTAGE OF RAINFALL, AND AVERAGE YEAR.

R. = Range.

APRIL.		MAY.		JUNE.		JULY.		AUGUST.		SEPTEMBER.		YEAR.		No. of Years.
M.	R.	M.	R.	M.	R.	M.	R.	M.	R.	M.	R.	Total.	R.	
	3.54		4.78		5.27		5.06		4.59		5.75		41.80	
2.77	1.37	2.99	0.27	3.78	2.10	4.34	3.76	3.88	3.22	3.73	1.08	36.76	33.48	5
	6.12		6.24		10.42		7.25		7.28		6.42		51.49	
3.71	2.25	2.97	1.12	5.46	1.86	5.00	3.72	5.56	3.45	4.70	1.94	47.86	39.77	5
	4.46		7.70		6.44		7.24		6.48		5.61		45.17	
2.76	1.27	3.96	1.27	3.98	2.77	4.11	2.42	4.16	1.92	3.04	1.41	39.38	31.62	14
	4.67		5.39		6.38		7.86		6.51		4.32		44.13	
2.70	1.50	2.73	1.11	4.46	2.94	5.05	4.03	4.49	2.73	2.90	1.40	39.85	31.77	6
	4.69		5.41		6.03		7.58		6.62		4.70		44.11	
2.89	1.33	3.20	1.74	4.11	2.94	4.62	2.77	4.14	2.26	2.83	1.05	40.02	33.04	10
	6.50		7.48		5.80		9.08		6.88		6.48		55.56	
3.28	1.57	4.04	2.18	4.32	2.50	4.55	2.54	3.74	1.30	3.07	1.56	41.71	33.47	21
	3.05		6.47		6.57		6.63		7.00		6.09		44.81	
2.61	1.34	3.77	1.97	4.15	1.81	4.15	2.28	3.50	1.69	2.65	1.32	36.86	29.37	10
	6.24		5.82		7.63		6.21		7.73		7.22		48.08	
2.55	1.16	3.85	2.28	4.90	2.09	4.14	2.17	3.56	1.41	2.95	1.01	38.33	30.47	10
	6.92		6.70		7.73		7.47		10.22		4.11		54.83	
3.07	1.72	3.75	1.78	5.13	3.55	4.06	2.35	4.50	1.54	3.24	1.98	42.98	30.58	7
	6.52		6.31		7.57		8.48		8.71		6.20		53.31	
2.66	1.57	4.20	1.25	4.78	3.34	4.42	2.27	3.67	1.61	3.17	1.06	41.17	30.45	10
	7.08		6.18		8.71		6.22		7.47		6.70		51.48	
2.70	1.19	4.04	1.33	4.78	2.72	4.09	2.18	3.82	1.46	3.24	0.73	40.76	32.48	10
	5.99		7.26		5.04		7.05		13.06		4.20		52.98	
3.09	1.08	3.96	1.72	3.99	3.20	4.13	1.94	6.24	2.70	2.89	2.29	42.98	30.80	5
	5.50		7.46		8.14		11.64		10.72		5.16		58.30	
2.80	1.67	4.18	0.93	4.77	1.90	4.91	3.08	3.80	0.98	3.32	1.22	42.68	35.19	9
	6.04		6.33		5.98		5.09		11.21		3.29		53.95	
3.35	1.48	4.07	1.92	4.53	2.83	4.92	2.68	5.15	2.40	2.77	1.86	43.80	34.00	5

APRIL.		MAY.		JUNE.		JULY.		AUGUST.		SEPTEMBER.		YEAR.		No. of Years.
M.	R.	L.	R.	M.	R.	M.	R.	M.	R.	M.	R	Total.	R.	
	7.10		4.80		3.20		1.51		1.53		1.82		27.04	
4.70	3.64	3.10	1.16	1.69	1.02	1.09	0.49	1.09	0.69	1.03	0.37	21.66	16.01	5
	6.43		4.50		4.28		2.49		2.19		2.25		36.94	
4.63	3.82	2.40	1.11	2.24	0.92	1.47	0.56	1.41	0.87	1.51	1.08	29.43	23.76	5
	4.83		4.54		3.03		3.25		1.60		1.42		28.03	
3.43	2.34	2.07	0.61	1.25	0.50	0.83	0.34	0.77	0.24	0.61	0.17	21.09	16.34	14
	4.46		2.52		1.79		3.41		1.53		1.44		27.18	
3.17	2.49	1.13	0.40	1.07	0.40	1.01	0.28	0.66	0.12	0.72	0.15	23.19	15.15	6
	5.45		3.15		2.44		4.11		1.44		1.24		27.60	
3.50	2.24	1.68	0.60	1.20	0.54	1.23	0.36	0.87	0.27	0.52	0.18	22.26	16.57	10
	6.84		5.10		3.37		3.49		1.88		2.50		34.20	
3.20	1.80	1.94	0.51	1.30	0.31	1.06	0.28	0.76	0.16	0.53	0.15	22.68	16.29	21
	4.60		3.22		2.18		1.52		2.66		0.88		21.46	
1.98	0.76	1.34	(0.31)	0.99	0.37	0.76	0.29	0.69	0.23	0.34	0.16	14.22	8.16	10
	4.79		3.36		3.07		1.71		3.15		0.93		19.78	
1.77	0.72	1.39	0.53	1.16	0.52	0.83	0.34	0.81	0.38	0.43	0.23	13.64	7.86	10
	4.45		3.45		3.05		1.45		3.08		1.25		24.73	
2.18	1.01	1.63	0.94	1.50	0.68	0.99	0.38	1.02	0.30	0.67	0.29	18.21	10.69	7
	4.98		3.55		3.15		3.02		2.71		0.99		26.30	
2.02	0.88	1.77	0.58	1.17	0.49	0.98	0.24	0.81	0.22	0.50	0.21	16.91	11.45	10
	4.20		2.83		3.00		2.82		2.49		2.14		21.33	
1.79	0.80	1.51	0.58	1.15	0.30	0.99	0.24	0.84	0.25	0.63	0.17	15.99	12.15	10
	3.67		3.19		1.51		1.31		4.01		1.18		25.15	
2.13	0.85	1.44	0.92	0.90	0.48	0.73	0.39	1.42	0.53	0.83	0.37	16.48	10.92	5
	4.90		4.36		2.54		3.54		5.73		1.53		29.66	
1.89	0.58	1.79	0.76	1.14	0.54	1.16	0.39	1.33	0.26	0.80	0.22	17.69	8.88	9
	3.49		3.16		1.73		2.43		4.94		1.45		25.16	
1.88	0.81	1.65	1.10	1.37	1.05	1.45	0.79	1.80	0.82	1.02	0.65	18.66	10.99	5

TABLE 3—

RUN-OFF, IN PERCENTAGE OF RAINFALL.

Drainage.	October.		November.		December.		January.		February.		March.	
	M.	R.	M.	R.	M.	R.	M.	R.	M.	R.	M.	R.
Connecticut, above Orford	41	92 17	57	132 33	46	103 17	33	55 13	34	86 23	114	163 45
Housatonic, above Gaylordsville	47	64 (18)	58	175 22	61	67 (37)	76	149 (41)	63	(87) (39)	143	203 87
Susquehanna, above Harrisburg	30	44 6	41	105 11	59	100 19	71	133 32	74	209 41	134	277 60
Susquehanna, above Wilkes-Barre	35	53 4	40	85 22	77	140 40	112	201 76	111	197 (47)	148	223 78
Susquehanna, above Williamsport	29	64 10	42	68 12	56	102 15	75	116 50	72	146 43	137	200 74
Ohio, above Wheeling	27	72 6	39	114 12	64	99 27	86	129 46	98	151 54	120	191 82
Potomac, above Point of Rocks	24	162 8	19	41 6	40	76 10	51	98 30	69	163 33	82	149 41
Shenandoah, above Millville	33	623 10	23	64 12	40	383 9	47	78 (27)	49	139 (26)	61	148 23
James, above Cartersville	25	131 13	36	69 23	46	70 21	56	74 31	60	108 34	81	128 44
James, above Buchanan	24	92 8	29	75 14	43	67 11	49	75 24	64	105 16	86	172 40
James, above Glasgow	26	381 8	28	64 11	42	653 12	49	73 34	66	168 51	70	127 37
Appomattox, above Mattoax	23	160 11	29	47 13	39	71 17	53	77 30	74	88 48	62	76 26
Roanoke, above Roanoke	31	208 9	31	77 15	39	92 7	50	90 13	60	152 15	72	115 27
Roanoke, above Randolph	40	180 25	36	89 17	43	53 24	53	71 36	56	116 (31)	65	103 41

LOSS, IN INCHES.

Drainage.	October.		November.		December.		January.		February.		March.	
	M.	R.	M.	R.	M.	R.	M.	R.	M.	R.	M.	R.
Connecticut, above Orford	1.75	2.60 0.18	0.94	3.03 —0.41	1.52	2.43 —0.06	1.52	1.97 0.91	1.06	2.15 0.10	—0.47	1.92 2.91
Housatonic, above Gaylordsville	2.09	3.24 0.98	1.00	3.33 —0.67	1.70	2.63 0.96	0.73	1.99 —1.05	0.95	2.36 (0.20)	—1.78	0.66 —4.46
Susquehanna, above Harrisburg	2.12	4.16 0.66	1.55	3.42 —0.11	1.22	2.76 0.00	0.79	1.84 —0.62	0.69	2.14 —1.21	—1.13	1.65 —3.58
Susquehanna, above Wilkes-Barre	2.17	3.45 1.27	1.45	3.46 0.17	0.77	1.70 —0.93	—0.32	0.83 —1.72	—0.26	0.65 —1.93	—1.73	0.80 —4.83
Susquehanna, above Williamsport	2.05	4.71 0.46	1.60	3.58 0.21	1.40	2.82 —0.03	0.67	1.50 —0.39	0.76	1.52 —0.84	—1.50	1.02 —4.05
Ohio, above Wheeling	1.94	3.96 0.39	1.88	4.76 —0.37	1.14	2.25 0.03	0.46	1.91 —0.88	0.07	0.90 —1.28	—0.68	0.69 —3.18
Potomac, above Point of Rocks	1.68	4.78 0.57	1.85	3.86 0.64	1.61	2.65 0.18	1.23	2.09 0.05	0.91	2.32 —0.75	0.62	2.60 —2.15
Shenandoah, above Millville	1.65	4.91 —2.51	1.60	3.48 0.29	1.56	3.00 —0.65	1.37	2.11 0.55	1.59	(3.67) —0.13	1.36	(2.40) —1.73
James, above Cartersville	2.57	(6.01) —0.17	1.14	2.67 0.29	1.77	3.90 0.95	1.40	1.93 0.83	1.41	2.31 —0.05	0.72	1.96 —0.92
James, above Buchanan	1.92	2.85 —0.20	1.71	3.83 0.50	1.70	3.07 —0.71	1.43	2.05 0.72	1.32	2.66 —0.03	0.53	2.62 —2.27
James, above Glasgow	1.94	6.22 —0.90	1.66	3.60 0.42	1.67	3.10 —0.94	1.45	1.88 0.86	1.23	2.30 —1.34	1.07	2.55 —0.86
Appomattox, above Mattoax	2.07	6.16 —0.21	1.56	2.67 0.56	2.30	5.77 0.86	1.52	2.09 0.76	0.82	1.62 0.40	1.38	2.27 0.71
Roanoke, above Roanoke	1.86	3.96 —0.14	1.71	3.91 0.43	1.63	3.33 0.04	1.42	2.61 0.39	1.57	4.10 —0.32	1.13	2.53 1.00
Roanoke, above Randolph	1.58	3.72 —0.56	1.41	2.13 0.14	2.24	4.23 1.05	1.47	2.06 0.82	1.58	2.73 —0.14	1.24	2.36 —0.09

(*Continued*).

April.		May.		June.		July.		August.		September.		Year.		No. of Years.
M.	R.	M.	R.	M.	R.	M.	R.	M.	R.	M.	R.	Mean.	R.	
	266		430		68		38		39		34		65	
170	120	104	65	45	20	25	13	28	16	28	22	59	46	5
	187		118		113		61		40		80		73	
125	105	81	72	41	20	29	11	25	18	32	17	62	53	5
	324		72		86		47		47		73		63	
124	25	52	21	31	10	20	9	18	6	20	5	55	44	14
	200		50		58		43		24		74		65	
117	96	41	26	24	10	20	7	15	4	25	11	58	47	6
	276		69		66		54		82		56		63	
121	85	52	34	29	12	27	12	21	7	18	7	56	42	10
	156		82		67		53		56		39		63	
98	58	48	18	30	10	23	9	20	5	17	6	54	44	21
	104		57		48		34		38		28		61	
76	35	36	(11)	24	11	18	9	20	10	13	4	39	22	10
	113		65		41		43		41		41		58	
69	31	36	14	24	13	20	11	23	10	15	5	36	21	10
	101		66		54		37		30		44		50	
71	48	43	32	29	18	24	12	23	11	21	8	42	33	7
	123		79		52		38		39		80		58	
76	40	42	19	25	14	22	8	22	5	16	8	41	28	10
	128		69		52		33		33		32		53	
66	37	37	18	24	9	24	10	22	6	19	6	39	33	10
	113		54		41		32		31		49		48	
69	42	36	24	23	13	18	9	23	14	29	14	38	30	5
	89		125		57		48		53		37		56	
66	25	43	75	24	14	24	12	35	8	24	7	41	25	9
	87		66		38		46		44		44		57	
56	31	41	23	30	21	29	16	35	24	37	25	43	32	5

April.		May.		June.		July.		August.		September.		Year.		No. of Years.
M.	R.	M.	R.	M.	R.	M.	R.	M.	R.	M.	R.	Total.	R.	
	−0.70		1.67		4.23		3.81		3.62		3.74		18.81	
−1.94	−3.62	−0.11	−1.39	2.09	1.05	3.25	2.41	2.79	2.00	2.70	0.71	15.10	12.84	5
	−0.20		1.74		6.14		5.06		5.71		5.19		22.56	
−0.92	−2.20	0.57	−0.22	3.22	−0.25	3.53	1.56	4.15	2.08	3.19	0.39	18.43	13.39	5
	1.37		3.16		5.57		4.41		5.25		4.81		21.04	
−0.67	−2.84	1.89	0.58	2.73	0.40	3.28	1.94	3.39	1.22	2.43	0.53	18.29	13.54	14
	0.21		2.87		5.30		4.53		5.10		3.76		18.61	
−0.46	−1.50	1.60	0.71	3.39	1.32	4.04	3.47	3.83	2.53	2.18	0.43	16.66	14.52	6
	0.47		2.26		5.05		4.58		5.18		4.39		20.89	
−0.61	−2.54	1.52	0.94	2.91	1.25	3.39	2.41	3.27	0.96	2.31	0.87	17.76	15.70	10
	2.00		3.14		4.91		6.07		5.44		4.50		24.86	
0.07	−1.56	2.10	0.95	3.02	1.33	3.50	2.26	2.98	1.09	2.53	0.81	19.02	15.18	21
	1.60		3.77		4.49		5.41		5.23		5.84		29.09	
0.63	−0.14	2.43	1.26	3.16	1.33	3.39	1.98	2.81	1.27	2.31	1.03	22.64	13.87	10
	1.82		3.97		5.14		5.11		4.58		6.83		33.05	
0.78	−0.30	2.46	1.46	3.74	1.49	3.31	1.73	2.75	1.03	2.52	0.76	24.69	14.58	10
	2.47		3.59		5.37		4.98		7.14		3.54		30.79	
0.89	−0.02	2.12	0.60	3.63	2.57	3.07	1.94	3.48	1.24	2.57	1.33	24.77	18.90	7
	1.54		4.10		5.77		5.46		6.00		5.21		32.38	
0.64	−0.37	2.43	0.26	3.60	2.79	3.44	1.87	2.86	1.30	2.67	0.83	24.26	14.89	10
	2.88		3.47		6.87		4.18		4.98		4.56		30.46	
0.91	−0.45	2.53	0.41	3.63	1.92	3.10	1.91	2.97	1.15	2.61	0.50	24.77	16.29	10
	2.51		4.07		4.04		6.42		9.05		3.46		36.10	
0.95	−0.41	2.52	0.79	3.09	2.19	3.40	1.51	4.82	2.17	2.07	1.22	26.50	19.88	5
	1.70		4.91		6.85		8.10		4.99		4.81		31.71	
0.91	0.20	2.39	−0.23	3.63	0.81	3.75	2.44	2.47	0.72	2.53	0.84	24.99	15.91	9
	2.55		4.95		4.75		6.30		6.27		1.99		29.38	
1.47	0.24	2.42	0.65	3.16	1.78	3.47	1.87	3.35	1.58	1.75	1.21	25.14	16.00	5

TABLE 4.—YEARLY RAINFALL, RUN-OFF, RUN-OFF IN PERCENTAGE OF RAINFALL, AND LOSS.

SUSQUEHANNA BASIN.

Period.	Precipitation.			Run-off, in Inches.			Run-off, in Percentage of Precipitation.			Total Loss, in Inches.		
	Harrisburg, 24 080 sq. miles.	Wilkes-Barre, 9 810 sq. miles.	Williamsport, 5 640 sq. miles.	Harrisburg.	Wilkes-Barre.	Williamsport.	Harrisburg.	Wilkes-Barre.	Williamsport.	Harrisburg.	Wilkes-Barre.	Williamsport.
1891–92	45.17	.....	.....	24.90	.....	.....	55	....	....	20.27	.....	.....
1892–93	39.57	.....	.....	20.85	.....	.....	53	....	....	18.72	.....	.....
1893–94	39.01	.....	.....	21.06	.....	.....	54	....	....	17.95	.....	.....
1894–95	33.74	.....	.....	20.20	.....	.....	60	....	....	13.54	.....	.....
1895–96	37.57	.....	37.46	16.53	.....	16.57	44	....	42	21.04	.....	20.89
1896–97	36.66	.....	39.79	19.04	.....	21.74	52	....	55	17.62	.....	18.05
1897–98	39.77	.....	40.27	21.26	.....	23.00	53	....	57	18.51	.....	17.27
1898–99	39.75	.....	41.15	20.02	.....	20.69	50	....	50	19.73	.....	20.46
1899–00	31.62	31.77	33.04	16.34	15.15	17.34	52	47	52	15.28	16.62	15.70
1900–01	42.47	42.89	44.11	22.22	24.28	24.18	51	57	55	20.25	18.61	19.93
1901–02	43.75	44.13	43.79	25.71	27.09	27.58	59	61	63	18.04	17.04	16.21
1902–03	44.87	41.70	43.73	28.03	27.18	27.60	63	65	63	16.84	14.52	16.13
1903–04	40.84	41.91	42.51	21.07	27.13	25.86	52	65	61	19.77	14.78	16.65
1904–05	36.49	36.73	34.30	18.26	18.35	18.01	50	50	53	18.23	18.38	16.29
Mean	39.38	39.85	40.02	21.09	23.19	22.26	55	58	56	18.29	16.66	17.76
Maximum	45.17	44.13	44.11	28.03	27.18	27.60	63	65	63	21.04	18.61	20.89
Minimum	31.62	31.77	33.04	16.34	15.15	16.57	44	47	42	13.54	14.52	15.70

POTOMAC BASIN.

Period.	Precipitation.		Run-off, in Inches.		Run-off, in Percentage of Precipitation.		Total Loss, in Inches.	
	Point of Rocks, 9 650 sq. miles.	Millville, 3 000 sq. miles.	Point of Rocks.	Millville.	Point of Rocks.	Millville.	Point of Rocks.	Millville.
1895–96	37.25	42.10	8.16	9.05	22	21	29.09	33.05
1896–97	32.60	31.67	16.53	16.03	51	51	16.07	15.68
1897–98	38.50	40.83	13.47	12.14	35	30	25.03	28.64
1898–99	41.72	43.04	18.38	14.84	44	34	23.32	28.20
1899–00	30.09	33.63	8.99	9.73	30	29	21.10	23.90
1900–01	43.63	48.08	17.22	19.44	39	40	26.40	28.64
1901–02	35.33	34.36	21.46	19.73	61	58	13.87	14.58
1902–03	44.81	44.91	19.36	19.60	43	44	25.45	25.32
1903–04	29.37	30.47	9.30	7.86	32	23	20.07	22.61
1904–05	35.28	34.20	9.34	8.01	26	23	25.94	26.19
Mean	36.86	38.33	14.22	13.64	39	36	22.64	24.69
Maximum	44.81	48.08	21.46	19.78	61	58	29.09	33.05
Minimum	29.37	30.47	8.16	7.86	22	21	13.87	14.58

TABLE 4—(*Continued*).

JAMES BASIN.

Period.	Precipitation.				Run-off, in Inches.				Run-off, in Percentage of Precipitation.				Total Loss, in Inches.			
	Cartersville, 6 230 sq. miles.	Buchanan, 2 060 sq. miles.	Glasgow, 830 sq. miles.	Mattoax, 745 sq. miles.	Cartersville.	Buchanan.	Glasgow.	Mattoax.	Cartersville.	Buchanan.	Glasgow.	Mattoax.	Cartersville.	Buchanan.	Glasgow.	Mattoax.
1895–96	.....	44.12	45.22	.....	.....	12.20	14.76	.....	....	28	33	....	.....	31.92	30.46	.....
1896–97	.....	34.25	32.92	.....	.....	17.10	16.63	.....	....	50	50	....	.....	17.15	16.29	.....
1897–98	.....	42.69	38.78	.....	.....	12.78	12.81	.....	....	30	33	....	.....	29.91	25.97	.....
1898–99	50.23	47.34	47.95	.....	22.20	21.28	17.35	.....	44	45	33	....	28.03	26.06	30.60	.....
1899–00	36.57	35.78	36.49	.....	13.60	12.04	12.15	.....	37	34	42	....	22.97	23.74	24.34	.....
1900–01	54.83	53.31	51.48	52.98	24.04	26.30	21.33	16.88	44	49	41	32	30.79	27.01	30.15	36.10
1901–02	37.83	35.72	35.54	38.13	18.93	20.83	18.81	17.51	50	58	53	46	18.90	14.89	16.73	20.62
1902–03	50.59	48.81	50.77	52.70	24.73	22.30	20.99	25.15	49	46	41	48	25.86	26.51	29.78	27.55
1903–04	30.58	30.45	32.48	30.80	10.69	11.45	12.78	10.92	35	38	39	35	19.89	19.00	19.70	19.88
1904–05	40.21	39.24	36.00	40.28	13.28	12.83	12.30	11.94	33	33	34	30	26.93	26.41	23.70	28.34
Mean	42.98	41.17	40.76	42.98	18.21	16.91	15.99	16.48	42	41	39	39	24.77	24.26	24.77	26.50
Maximum	54.83	53.31	51.48	52.98	24.73	26.30	21.33	25.15	50	58	53	48	30 79	32.38	30.46	36.10
Minimum	30.58	30.45	32.48	30.80	10.69	11.45	12.15	10.92	33	28	33	30	18.90	14.89	16.29	19.88

ROANOKE BASIN.

Period.	Precipitation.		Run-off, in Inches.		Run-off, in Percentage of Precipitation.		Total Loss, in Inches.	
	Randolph. 3 080 sq. miles.	Roanoke, 390 sq. miles.	Randolph.	Roanoke.	Randolph.	Roanoke.	Randolph.	Roanoke.
1896–97	.....	35.19	.....	14.90	.....	42	.....	20.29
1897–98	.....	38.28	.....	12.12	.....	32	.....	26 16
1898–99	.....	48.85	.....	27.32	.....	56	.....	21.53
1899–00	.....	38.08	.....	12.32	.....	32	.....	25.76
1900–01	53.95	58.30	25.16	29.66	47	51	28.79	28.64
1901–02	37.14	34.47	21.14	18.56	57	54	16,00	15,91
1902–03	50.99	49.73	22.50	21.15	44	43	28,49	28,58
1903–04	34.00	35.21	10.99	8.88	32	25	23,01	26,33
1904–05	42.69	46.03	13.51	14.32	32	31	29,38	31.71
Mean	43.80	42.68	18,66	17.69	43	41	25,14	24,99
Maximum	53.95	58.30	25.16	29.66	57	56	29,38	31,71
Minimum	34.00	34.47	10.99	8.88	32	25	16,00	15.91

TABLE 5.—YEARLY RAINFALL, RUN-OFF, RUN-

Period.	RAINFALL, IN INCHES.							RUN-OFF, IN INCHES.						
	Connecticut, above Orford, N. H. 3 300 sq. miles.	Housatonic, above Gaylordsville, Conn. 1 020 sq. miles.	Susquehanna, above Harrisburg, Pa. 24 080 sq. miles.	Ohio, above Wheeling, W. Va. 23 830 sq. miles.	Potomac, above Point of Rocks, Md. 9 650 sq. miles.	James, above Cartersville, Va. 6 230 sq. miles.	Roanoke, above Roanoke, Va. 390 sq. miles.	Connecticut, above Orford, N. H.	Housatonic, above Gaylordsville, Conn.	Susquehanna, above Harrisburg, Pa.	Ohio, above Wheeling, W. Va.	Potomac, above Point of Rocks, Md.	James, above Cartersville, Va.	Roanoke, above Roanoke, Va.
1884–85	.....	.....	.....	39.12	.....	.....	.....	.....	.....	.....	17.82	.....	.....	.....
1885–86	.....	.....	.....	39.89	.....	.....	.....	.....	.....	.....	21.18	.....	.....	.....
1886–87	.....	.....	.....	39.34	.....	.....	.....	.....	.....	.....	22.39	.....	.....	.....
1887–88	.....	.....	.....	37.46	.....	.....	.....	.....	.....	.....	17.46	.....	.....	.....
1888–89	.....	.....	.....	39.52	.....	.....	.....	.....	.....	.....	24.34	.....	.....	.....
1889–90	.....	.....	.....	55.56	.....	.....	.....	.....	.....	.....	34.20	.....	.....	.....
1890–91	.....	.....	.....	48.63	.....	.....	.....	.....	.....	.....	30.64	.....	.....	.....
1891–92	.....	.....	45.17	43.40	.....	.....	.....	.....	.....	24.90	22.09	.....	.....	.....
1892–93	.....	.....	39.57	39.40	.....	.....	.....	.....	.....	20.85	21.52	.....	.....	.....
1893–94	.....	.....	39.01	38.55	.....	.....	.....	.....	.....	21.06	18.03	.....	.....	.....
1894–95	.....	.....	33.74	33.47	.....	.....	.....	.....	.....	20.20	16.29	.....	.....	.....
1895–96	.....	.....	37.57	44.57	37.25	.....	.....	.....	.....	16.53	19.71	8.16	.....	.....
1896–97	.....	.....	36.66	38.44	32.60	.....	35.19	.....	.....	19.04	22.59	16.53	.....	14.90
1897–98	.....	.....	39.77	46.51	38.50	.....	38.28	.....	.....	21.26	24.61	13.47	.....	12.12
1898–99	.....	.....	39.75	43.26	41.72	50.23	48.85	.....	.....	20.02	22.88	18.38	22.20	27.32
1899–00	.....	.....	31.62	35.94	30.09	36.57	38.08	.....	.....	16.34	17.64	8.99	13.60	12.32
1900–01	38.93	48.24	42.47	45.21	43.63	54.83	58.30	24.00	25.68	22.22	24.55	17.22	24.04	29.66
1901–02	41.80	51.49	43.75	40.78	35.33	37.83	34.47	27.04	33.17	25.71	24.66	21.46	18.93	18.56
1902–03	34.76	50.33	44.87	45.20	44.81	50.59	49.73	21.92	36.94	28.03	27.09	19.36	24.73	21.15
1903–04	34.82	49.48	40.84	41.62	29.37	30.58	35.21	16.01	27.61	21.07	25.35	9.30	10.69	8.88
1904–05	33.48	39.77	36.49	39 91	35.28	40.21	46.03	19.31	23.76	18.26	21.19	9.34	13.28	14.32
Mean	36.76	47.86	39.38	41.71	36.86	42.98	42.68	21.66	29.43	21.09	22.68	14.22	18.21	17.69
Maximum	41.80	51.49	45.17	55.56	44.81	54.83	58.30	27.04	36.94	28.03	34.20	21.46	24.73	29.66
Minimum	33.48	39.77	31.62	33.47	29.37	30.58	34.47	16.01	23.76	16.34	16.29	8.16	10.69	8.88

OFF IN PERCENTAGE OF RAINFALL, AND LOSS.

Run-off, in Percentage of Rainfall.							Total Loss, in Inches.							Period.
Connecticut, above Orford, N. H.	Housatonic, above Gaylordsville, Conn.	Susquehanna, above Harrisburg, Pa.	Ohio, above Wheeling, W. Va.	Potomac, above Point of Rocks, Md.	James, above Cartersville, Va.	Roanoke, above Roanoke, Va.	Connecticut, above Orford, N. H.	Housatonic, above Gaylordsville, Conn.	Susquehanna, above Harrisburg, Pa.	Ohio, above Wheeling, W. Va.	Potomac, above Point of Rocks, Md.	James, above Cartersville, Va.	Roanoke, above Roanoke, Va.	
.....	.....	.....	46	.....	.....	.....	.....	.....	.....	21.30	.....	.....	.....	1884–85
.....	.....	.....	53	.....	.....	.....	.....	.....	.....	18.71	.....	.....	.....	1885–86
.....	.....	.....	57	.....	.....	.....	.....	.....	.....	16.95	.....	.....	.....	1886–87
.....	.....	.....	47	.....	.....	.....	.....	.....	.....	20.00	.....	.....	.....	1887–88
.....	.....	.....	62	.....	.....	.....	.....	.....	.....	15.18	.....	.....	.....	1888–89
.....	.....	.....	62	.....	.....	.....	.....	.....	.....	21.36	.....	.....	.....	1889–90
.....	.....	.....	63	.....	.....	.....	.....	.....	.....	17.99	.....	.....	.....	1890–91
.....	.....	55	51	.....	.....	.....	.....	.....	20.27	21.31	.....	.....	.....	1891–92
.....	.....	53	55	.....	.....	.....	.....	.....	18.72	17.88	.....	.....	.....	1892–93
.....	.....	54	47	.....	.....	.....	.....	.....	17.95	20.52	.....	.....	.....	1893–94
.....	.....	60	49	.....	.....	.....	.....	.....	13.54	17.18	.....	.....	.....	1894–95
.....	.....	44	44	22	.....	.....	.....	.....	21.04	24.86	29.09	.....	.....	1895–96
.....	.....	52	59	51	.....	42	.....	.....	17.62	15.85	16.07	.....	20.29	1896–97
.....	.....	53	53	35	.....	32	.....	.....	18.51	21.90	25.03	.....	26.16	1897–98
.....	.....	50	53	44	44	56	.....	.....	19.73	20.38	23.32	28.03	21.53	1898–99
.....	.....	52	49	30	37	32	.....	.....	15.28	18.30	21.10	22.97	25.76	1899–00
62	53	51	54	39	44	51	14.93	22.56	20.25	20.48	26.40	30.79	28.64	1900–01
65	64	59	60	61	50	54	14.76	18.32	18.04	16.12	13.87	18.90	15.91	1901–02
63	73	63	60	43	49	43	12.84	13.39	16.84	18.11	25.45	25.86	28.58	1902–03
46	56	52	61	32	35	25	18.81	21.87	19.77	16.27	20.07	19.89	26.33	1903–04
58	60	50	53	26	33	31	14.17	16.01	18.23	18.72	25.94	26.93	31.71	1904–05
59	62	55	54	39	42	41	15.10	18.43	18.29	19.02	22.64	24.77	24.99	Mean.
65	73	62	63	61	50	56	18.81	22.56	21.04	24.86	29.09	30.79	31.71	Maximum.
46	53	44	44	22	33	25	12.84	13.39	13.54	15.18	13.87	18.90	15.91	Minimum.

TABLE 6.—RAINFALL, RUN-OFF, RUN-OFF IN PERCENTAGE OF RAINFALL, AND LOSS, FOR THE WINTER AND THE SUMMER MONTHS.

CONNECTICUT, AT ORFORD, N. H.

Year.	Winter Months, Nov. to Apr., Inclusive.				Summer Months, June, July, August.				Loss for year.
	Rainfall.	Run-off.	Percentage of run-off.	Loss.	Rainfall.	Run-off.	Percentage of run-off.	Loss.	
1900–1901	11.43	12.10	106	—0.67	11.07	4.21	38	6.86	14.93
1901–1902	16.99	14.78	87	2.21	12.59	6.22	49	6.37	14.76
1902–1903	15.53	14.60	94	0.93	12.49	2.59	21	9.90	12.84
1903–1904	11.60	6.81	59	4.79	10.17	2.20	22	7.97	18.81
1904–1905	8.87	7.66	86	1.21	13.65	4.12	30	9.53	14.17
Mean	12.89	11.19	87	1.70	12.00	3.87	32	8.13	15.10
Maximum	16.99	14.78	106	4.79	13.65	6.22	49	9.90	18.81
Minimum	8.87	6.81	59	—0.67	10.17	2.20	21	6.37	12.84

HOUSATONIC, ABOVE GAYLORDSVILLE, CONN.

1900–1901	16.45	14.20	86	2.25	14.15	4.44	31	9.71	22.56
1901–1902	20.91	21.63	103	—0.72	16.11	5.04	31	11.07	18.32
1902–1903	20.23	21.40	106	—1.17	21.48	8.96	42	12.52	13.39
1903–1904	16.92	13.61	80	3.31	13.93	4.83	35	9.10	21.87
1904–1905	14.48	14.74	102	—0.26	14.43	2.35	16	12.08	16.01
Mean	17.80	17.12	96	0.68	16.02	5.12	32	10.90	18.43
Maximum	20.91	21.63	106	3.31	21.48	8.96	42	12.52	22.56
Minimum	14.48	13.61	80	—1.17	13.93	2.35	16	9.10	13.39

SUSQUEHANNA, ABOVE HARRISBURG, PA.

1891–1892	15.85	13.97	88	1.88	14.93	4.71	32	10.22	20.27
1892–1893	14.87	13.20	89	1.67	11.25	1.62	14	9.63	18.72
1893–1894	13.49	11.00	82	2.49	7.42	3.11	42	4.31	17.95
1894–1895	11.99	14.17	118	—2.18	10.06	1.20	12	8.86	13.54
1895–1896	15.29	12.97	85	2.32	11.40	2.32	20	9.08	21.04
1896–1897	11.39	10.76	94	0.63	10.88	2.09	19	8.79	17.62
1897–1898	15.14	14.06	93	1.08	12.24	2.56	21	9.68	18.51
1898–1899	13.51	13.75	102	—0.24	10.09	1.26	12	8.83	19.73
1899–1900	13.96	12.99	93	0.97	9.67	1.19	12	8.48	15.28
1900–1901	12.84	12.02	94	0.82	13.16	4.81	37	8.35	20.25
1901–1902	18.10	17.97	99	0.13	16.17	5.14	32	11.03	18.04
1902–1903	18.84	19.15	102	—0.31	17.44	4.09	23	13.35	16.84
1903–1904	14.60	12.50	86	2.10	12.26	2.72	22	9.54	19.77
1904–1905	12.82	11.82	92	1.00	14.40	3.13	22	11.27	18.23
Mean	14.48	13.58	94	0.90	12.25	2.85	23	9.40	18.29
Maximum	18.84	19.15	118	2.49	17.44	5.14	42	13.35	21.04
Minimum	11.39	10.76	82	—2.18	7.42	1.19	12	4.31	13.54

TABLE 6—*(Continued)*.

SUSQUEHANNA, ABOVE WILKES-BARRE, PA.

Year.	Winter Months, Nov. to Apr., Inclusive.				Summer Months, June, July, August.				Loss for year.
	Rainfall.	Run-off.	Percentage of run-off.	Loss.	Rainfall.	Run-off.	Percentage of run-off.	Loss.	
1899–1900	14.17	12.42	88	1.75	9.80	0.88	9	8.92	16.62
1900–1901	13.18	16.90	128	—3.72	13.10	3.01	23	10.09	18.61
1901–1902	16.66	20.85	125	—4.19	16.61	4.10	25	12.51	17.04
1902–1903	16.68	19.20	115	—2.52	17.28	3.62	21	13.66	14.52
1903–1904	13.79	17.80	129	—4.01	12.49	2.31	18	10.18	14.78
1904–1905	12.32	11.72	95	0.60	14.77	2.49	17	12.28	18.38
Mean	14.47	16.48	114	—2.01	14.00	2.74	20	11.26	16.66
Maximum	16.68	20.85	129	1.75	17.28	4.10	25	13.66	18.61
Minimum	12.32	11.72	88	—4.19	9.80	0.88	9	8.92	14.52

SUSQUEHANNA, AT WILLIAMSPORT, PA.

1895–1896	14.53	10.97	76	3.56	12.49	4.06	33	8.43	20.89
1896–1897	13.22	12.01	91	1.21	11.76	2.06	18	9.70	18.05
1897–1898	16.95	16.78	101	0.17	11.76	2.18	19	9.58	17.27
1898–1899	14.50	14.44	100	0.06	10.55	1.17	11	9.38	20.46
1899–1900	15.32	13.31	87	2.01	9.81	1.49	15	8.32	15.70
1900–1901	13.27	13.10	99	0.17	14.10	4.48	32	9.62	19.93
1901–1902	18.41	19.23	104	—0.82	16.02	5.78	36	10.24	16.21
1902–1903	18.53	19.84	107	—1.31	16.77	4.79	29	11.98	16.13
1903–1904	17.57	16.71	95	0.86	11.75	3.01	26	8.74	16.65
1904–1905	12.52	11.25	90	1.27	13.68	4.00	29	9.68	16.29
Mean	15.48	14.76	95	0.72	12.87	3.30	26	9.57	17.76
Maximum	18.53	19.84	107	3.56	16.77	5.78	33	11.98	20.89
Minimum	12.52	10.97	76	—1.31	9.81	1.17	11	8.32	15.70

TABLE 6—(*Continued*).

OHIO, ABOVE WHEELING, W. VA.

Year.	Winter Months, Nov. to Apr., Inclusive.				Summer Months. June, July, August.				Loss for year.
	Rainfall.	Run-off.	Percentage of run-off.	Loss.	Rainfall.	Run-off.	Percentage of run-off.	Loss.	
1884-1885	14.09	11.80	84	2.29	14.66	3.12	21	11.54	21.30
1885-1886	14.30	15.11	106	—0.81	10.84	2.00	18	8.84	18.71
1886-1887	16.71	16.19	97	0.52	10.73	1.68	16	9.05	16.95
1887-1888	13.46	10.95	81	2.51	12.58	3.79	30	8.79	20.00
1888-1889	12.90	12.12	94	0.78	11.59	5.44	47	6.15	15.18
1889-1890	22.03	20.51	93	1.52	12.39	2.66	21	9.73	21.36
1890-1891	18.70	18.95	101	—0.25	15.29	3.99	26	11.30	17.99
1891-1892	15.99	13.50	84	2.49	12.70	3.75	30	8.95	21.31
1892-1893	17.87	14.96	84	2.91	9.83	1.20	12	8.63	17.88
1893-1894	15.75	11.99	76	3.76	6.34	1.66	26	4.68	20.52
1894-1895	14.25	13.23	93	1.02	9.91	1.04	10	8.87	17.18
1895-1896	14.93	12.27	82	2.66	17.14	5.57	33	11.57	24.86
1896-1897	14.93	14.61	98	0.32	12.87	2.63	20	10.24	15.85
1897-1898	19.34	17.80	92	1.54	14.46	3.10	21	11.36	21.90
1898-1899	15.39	15.48	99	—0.09	11.01	2.06	19	8.95	20.38
1899-1900	15.24	13.94	91	1.30	12.57	1.93	15	10.64	18.30
1900-1901	15.77	15.99	101	—0.22	12.57	3.35	27	9.22	20.48
1901-1902	16.39	17.07	104	—0.68	14.56	5.12	35	9.44	16.12
1902-1903	20.73	20.79	100	—0.06	15.09	3.54	23	11.55	18.11
1903-1904	17.46	17.43	100	0.03	11.99	3.43	29	8.56	16.27
1904-1905	14.56	13.81	95	0.75	15.75	4.39	28	11.36	18.72
Mean	16.23	15.16	93	1.07	12.61	3.12	25	9.49	19.02
Maximum	22.03	20.51	106	3.76	17.14	5.57	47	11.57	24.86
Minimum	12.90	10.95	76	—0.81	6.34	1.04	10	6.15	15.18

POTOMAC, ABOVE POINT OF ROCKS, MD.

1895-1896	13.20	5.16	39	8.04	12.49	2.15	17	10.34	29.09
1896-1897	12.85	9.41	73	3.44	9.44	1.82	19	7.62	16.07
1897-1898	14.87	7.11	48	7.76	12.02	3.43	29	8.59	25.03
1898-1899	15.22	12.92	85	2.30	8.59	1.19	14	7.40	23.32
1899-1900	12.24	6.17	50	6.07	10.01	1.56	16	8.45	21.10
1900-1901	13.69	7.97	58	5.72	14.61	4.46	31	10.15	26.40
1901-1902	19.92	18.50	93	1.42	8.36	1.03	12	7.33	13.87
1902-1903	18.84	13.24	70	5.60	14.91	4.18	28	10.73	25.45
1903-1904	8.57	5.37	63	3.20	11.64	2.00	17	9.64	20.07
1904-1905	11.98	5.46	46	6.52	15.94	2.68	17	13.26	25.94
Mean	14.14	9.14	65	5.00	11.80	2.44	21	9.36	22.64
Maximum	19.92	18.50	93	8.04	15.94	4.46	31	13.26	29.09
Minimum	8.57	5.16	39	1.42	8.36	1.03	12	7.33	13.87

TABLE 6—(*Continued*).

SHENANDOAH, ABOVE MILLVILLE, W. VA.

Year.	Winter Months, Nov. to Apr., Inclusive.				Summer Months, June, July, August.				Loss for year.
	Rainfall.	Run-off.	Percentage of run-off.	Loss.	Rainfall.	Run-off.	Percentage of run-off.	Loss.	
1895-1896	14.85	5.10	34	9.75	15.12	2.30	15	12.82	33.05
1896-1897	12.16	8.17	67	3.99	8.73	1.54	18	7.19	15.68
1897-1898	13.70	4.60	34	9.10	14.77	4.24	29	10.53	28.64
1898-1899	16.88	8.93	53	7.95	8.54	1.32	15	7.22	28.20
1899-1900	13.25	6.31	48	6.94	11.67	1.69	14	9.98	23.90
1900-1901	14.51	8.11	56	6.40	17.84	6.14	34	11.70	28.64
1901-1902	19.11	15.98	84	3.13	7.32	1.35	18	5.97	14.58
1902-1903	18.72	12.31	66	6.41	14.22	4.72	33	9.50	25.32
1903-1904	8.74	3.58	41	5.16	13.14	2.06	16	11.08	22.61
1904-1905	11.80	4.08	35	7.72	14.67	2.70	18	11.97	26.19
Mean	14.38	7.72	54	6.66	12.60	2.80	22	9.80	24.69
Maximum	19.11	15.98	84	9.75	17.84	6.14	34	12.82	33.05
Minimum	8.74	3.58	34	3.13	8.54	1.32	14	5.97	14.58

JAMES, ABOVE CARTERSVILLE, VA.

1898-1899	20.45	15.07	74	5.38	11.83	1.66	14	10.15	28.03
1899-1900	16.26	8.94	55	7.32	9.86	2.27	23	7.59	22.97
1900-1901	16.44	9.78	60	6.66	21.07	7.58	36	13.49	30.79
1901-1902	20.54	14.70	72	5.84	8.98	1.66	18	7.32	18.90
1902-1903	21.63	15.75	73	5.88	15.17	4.48	30	10.69	25.86
1903-1904	10.43	5.32	51	5.11	11.33	2.32	20	9.01	19.89
1904-1905	12.89	5.78	45	7.11	17.55	4.57	26	12.98	26.93
Mean	16.95	10.76	63	6.19	13.69	3.51	26	10.18	24.77
Maximum	21.63	15.75	74	7.32	21.07	7.58	36	13.49	30.79
Minimum	10.43	5.32	45	5.11	8.98	1.66	14	7.32	18.90

JAMES, ABOVE BUCHANAN, VA.

1895-1896	16.85	7.17	43	9.68	15.31	2.91	19	12.40	31.92
1896-1897	12.89	10.65	83	2.24	9.29	1.49	16	7.80	17.15
1897-1898	14.47	6.32	44	8.15	14.14	3.21	23	10.93	29.91
1898-1899	18.14	14.50	80	3.64	10.61	1.10	10	9.51	26.06
1899-1900	15.36	8.72	57	6.64	10.54	1.90	18	8.64	23.74
1900-1901	15.94	11.12	70	4.81	19.55	7.32	37	12.23	27.01
1901-1902	20.72	17.99	87	2.73	7.57	1.21	16	6.36	14.89
1902-1903	22.29	16.02	72	6.27	14.04	3.47	25	10.57	26.51
1903-1904	10.34	5.86	57	4.48	11.69	2.52	22	9.17	19.00
1904-1905	12.85	5.38	42	7.47	16.00	4.51	28	11.49	26.41
Mean	15.99	10.37	65	5.62	12.87	2.97	23	9.90	24.26
Maximum	22.29	17.99	87	10.14	19.55	7.32	37	12.40	31.92
Minimum	10.34	5.38	43	2.24	7.57	1.10	10	6.36	14.89

TABLE 6—(*Continued*).

NORTH (OF JAMES) ABOVE GLASGOW, VA.

Year.	Winter Months, Nov. to Apr., Inclusive.				Summer Months, June, July, August.				Loss for year.
	Rainfall.	Run-off.	Percentage of run-off.	Loss.	Rainfall.	Run-off.	Percentage of run-off.	Loss.	
1895–1896	16.94	7.67	45	9.27	15.68	3.43	22	12.25	30.46
1896–1897	11.88	9.24	78	2.64	9.58	1.44	15	8.14	16.29
1897–1898	12.94	5.52	43	7.42	12.67	3.90	31	8.77	25.97
1898–1899	18.90	11.74	62	7.16	10.61	0.82	8	9.79	30.60
1899–1900	15.28	8.26	54	7.02	10.21	2.15	21	8.06	24.34
1900–1901	16.33	9.33	57	7.09	18.55	6.67	36	11.88	30.15
1901–1902	20.31	16.14	79	4.17	6.93	0.98	14	5.95	16.73
1902–1903	21.82	14.78	68	7.04	16.76	3.46	21	13.30	29.78
1903–1904	11.43	7.55	66	3.88	11.28	2.38	21	8.90	19.70
1904–1905	13.06	5.45	42	7.61	14.60	4.54	31	10.06	23.70
Mean	15.89	9.57	60	6.32	12.69	2.98	23	9.71	24.77
Maximum	21.82	16.14	79	9.27	18.55	6.67	36	13.30	30.46
Minimum	11.43	5.45	42	2.64	6.93	0.82	8	5.95	16.29

APPOMATTOX, ABOVE MATTOAX, VA.

1900–1901	16.70	6.74	40	9.96	19.93	5.61	28	14.32	36.10
1901–1902	21.83	13.04	60	8.79	10.54	2.11	20	8.43	20.62
1902–1903	22.86	16.55	72	6.31	13.99	3.90	28	10.09	27.55
1903–1904	9.91	5.90	60	4.01	10.74	1.72	16	9.02	19.88
1904–1905	13.03	7.24	56	5.79	16.60	1.90	11	14.70	28.34
Mean	16.87	9.89	59	6.98	14.36	3.05	21	11.31	26.50
Maximum	22.86	16.55	72	9.96	19.93	5.61	28	14.70	36.10
Minimum	9.91	5.90	40	4.01	10.54	1.72	11	8.43	19.88

ROANOKE, ABOVE ROANOKE, VA.

1896–1897	14.65	8.26	56	6.39	9.45	2.16	23	7.29	20.29
1897–1898	12.67	4.74	37	7.93	10.73	3.08	29	7.65	26.16
1898–1899	21.47	19.80	92	1.67	11.91	1.50	13	10.41	21.53
1899–1900	15.73	8.27	53	7.46	10.43	2.12	20	8.31	25.76
1900–1901	16.14	10.34	64	5.80	23.04	10.82	47	12.22	28.64
1901–1902	20.26	15.03	74	5.23	8.06	1.23	15	6.83	15.91
1902–1903	22.31	14.50	65	7.81	12.97	2.87	22	10.10	28.58
1903–1904	9.95	3.23	32	6.72	16.55	3.32	20	13.23	26.33
1904–1905	15.29	4.43	29	10.86	18.22	5.56	30	12.66	31.71
Mean	16.50	9.84	60	6.66	13.48	3.63	27	9.85	24.99
Maximum	22.31	19.80	92	10.86	23.04	10.82	47	13.23	31.71
Minimum	9.95	3.23	29	1.67	8.06	1.23	13	6.83	15.91

TABLE 6—(*Continued*).

ROANOKE, ABOVE RANDOLPH, VA.

Station.	Winter Months, Nov. to Apr., Inclusive.				Summer Months, June, July, August.				Total yearly loss.
	Rainfall.	Run-off.	Percentage of run-off.	Loss.	Rainfall.	Run-off.	Percentage of run-off.	Loss.	
1900–1901	16.56	9.50	57	7.06	20.81	9.01	43	11.80	28.79
1901–1902	21.26	13.95	66	7.31	9.06	2.96	33	6.10	16.00
1902–1903	24.65	13.88	56	10.77	12.91	3.43	27	9.48	28.49
1903–1904	10.17	4.64	46	5.53	14.47	3.11	22	11.36	23.01
1904–1905	14.94	5.61	38	9.33	15.79	4.63	29	11.16	29.38
Mean	17.53	9.53	54	8.00	14.60	4.62	32	9.98	25.14
Maximum	24.65	13.95	66	10.77	20.81	9.01	43	11.80	29.98
Minimum	10.17	4.64	38	5.53	9.06	2.96	22	6.10	16.00

FOR THE MEAN YEAR.

Connecticut, at Orford, N. H.	12.89	11.19	87	1.70	12.00	3.87	32	8.13	15.10
Housatonic, at Gaylordsville, Conn.	17.80	17.12	96	0.68	16.02	5.12	32	10.90	18.43
Susquehanna, at Harrisburg, Pa.	14.48	13.58	94	0.90	12.25	2.85	23	9.40	18.29
Susquehanna, at Wilkes-Barre, Pa.	14.47	16.48	114	—2.01	14.00	2.74	20	11.26	16.66
Susquehanna, at Williamsport, Pa.	15.48	14.76	95	0.72	12.87	3.30	26	9.57	17.76
Ohio, at Wheeling, W. Va.	16.23	15.16	93	1.07	12.61	3.12	25	9.49	19.02
Potomac, at Point of Rocks, Md.	14.14	9.14	65	5.00	11.80	2.44	21	9.36	22.64
Shenandoah, at Millville, W. Va.	14.38	7.72	54	6.66	12.62	2.80	22	9.80	24.69
James, at Cartersville, Va.	16.95	10.76	63	6.19	13.69	3.51	26	10.18	24.77
James, at Buchanan, Va.	15.99	10.37	65	5.62	12.87	2.97	23	9.90	24.26
North (of James) Glasgow, Va.	15.89	9.57	60	6.32	12.69	2.98	23	9.71	24.77
Appomattox, at Mattoax, Va.	16.87	9.89	59	6.98	14.36	3.05	21	11.31	26.50
Roanoke, at Roanoke, Va.	16.50	9.84	60	6.66	13.48	3.63	27	9.85	24.99
Roanoke, at Randolph, Va.	17.53	9.53	54	8.00	14.60	4.62	32	9.98	25.14

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

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A SOLUTION OF THE PROBLEM OF DETERMINING THE ECONOMIC SIZE OF PIPE FOR HIGH-PRESSURE WATER-POWER INSTALLATION.

By Arthur L. Adams, M. Am. Soc. C. E.

To be Presented June 5th, 1907.

In discussing a paper* by Edwin H. Warner, M. Am. Soc. C. E., descriptive of a large water-power installation, the writer called attention to the interesting problem of design, in such installations, involved in the determination of the most economic size of pressure pipe.

Between the pipe of infinite diameter which would be necessary to utilize the entire static pressure, and a pipe of diameter so small that the entire head would be consumed in initial velocity at entrance and in overcoming resistances, there is, of course, some point representing the most economic adjustment.

At that time, the writer, reasoning from analogy, suggested that Sir William Thomas' law for electric transmission, requiring

* "The Hydraulic Plant of the Puget Sound Power Company," *Transactions*, Am. Soc. C. E., Vol. LV, p. 228.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

that "the relation between the investment in copper and the cost of the power consumed in line losses should be such that the annual interest on capital outlay should equal the annual cost of the energy wasted," was also applicable to the transmission of power through the medium of water flowing in pressure pipe.

More deliberate consideration of the subject has convinced the writer that this conclusion was wrong. He is able now, however, not only to present what he feels confident is the correct solution; but also, as a result, to state a very simple rule applying to all such cases with sufficient exactness, which he hopes and believes will be of substantial value to the profession.

This solution is based upon the following proposition, which is self-evident: That the relation between the investment in any pipe line and the value of the energy lost in frictional resistance to flow is most economical wherein the cost of the pipe plus the value of the energy sacrificed is a minimum. Or, if one chooses to state it in terms of the annual cost: Wherein the annual cost of the pipe line plus the value of the energy annually sacrificed is a minimum. The writer has worked out the solution on the basis of the first manner of stating, but, as will be seen, the rule is equally applicable to either proposition. Table 1 is self-explanatory, and is made the basis of the graphical solution hereinafter referred to.

In compiling Table 1, the frictional loss is computed by the Chezy formula, $S = \left(\frac{V}{C\sqrt{R}}\right)^2$, in which V is the velocity, in feet per second; R is the hydraulic radius (one-fourth the diameter); C is a coefficient taken in this table uniformly at 100; and S is the frictional loss, in feet per linear foot of pipe. It will be observed that the frictional coefficient, C, is taken as a constant. For riveted pipes, the type generally used, this is fully warranted by the results of experiment, while, for other classes of conduit, which have been in use for a considerable length of time, such an assumption will lead to no material error.

Two other assumptions are deserving of mention: First, no account is taken of the additional thickness necessary at the upper end of the pipe line irrespective of the requirements to resist pressure, an item of negligible importance in the solution of this problem; and second, laps, rivets and overweights or sheets are not

included in computing the weight of the pipes, as these may be regarded as bearing a constant relation to the weight of the pipe, and consequently will not affect the rule sought. The weight of pipes for given pressures, therefore, is taken as proportional to the squares of their diameters, an assumption which is substantially correct.

TABLE 1.—COMPARATIVE DATA FOR THE STUDY OF THE MOST ECONOMIC DIAMETER OF PIPE TO BE INSTALLED FOR CONDUCTING 100 CU. FT. OF WATER PER SECOND FROM A HEAD-RACE TO THE WATER-WHEELS; THE PIPE BEING ASSUMED AS VERTICAL, AND 1 000 FT. IN LENGTH.

(1) Diameter of pipe, in inches.	(2) Friction loss, in feet in 500 ft. (= ¼ total length).	(3) Average dynamic pressure, in feet.	(4) Average strain in pipe shell, in pounds per square inch.	(5) Average thickness of pipe, in inches, at a strain of 10 000 lb. per sq. in.	(6) Weight of pipe, in pounds per foot, without allowance for seams or overweight.	(7) Cost of pipe per foot, at 7 cents per lb.	(8) Value of energy lost in friction in 1 000 ft., at $100 per horse-power.	(9) Value of energy lost in friction in 1 000 ft., at $50 per horse-power.
30	33.3	466.7	3 024	0.302	97.5	6.83	75 440	37 720
33	20.6	479.4	3 417	0.342	121.5	8.50	46 683	23 342
36	13.4	486.6	3 783	0.378	146.5	10.26	30 357	15 178
39	9.0	491.0	4 136	0.414	173.8	12.17	20 389	10 195
42	6.2	493.8	4 480	0.448	202.8	14.20	14 047	7 023
45	4.4	495.6	4 817	0.482	233.3	16.35	9 968	4 984
48	3.2	496.8	5 151	0.515	271.6	19.01	7 249	3 624
54	1.8	498.2	5 811	0.581	338.3	23.68	4 078	2 039
60	1.1	498.9	6 465	0.647	418.4	29.29	2 492	1 246
66	0.8	499.2	7 116	0.712	506.6	35.46	1 812	906

The diagram, Fig. 1, presents four curves, designated as *A*, *B*, *C*, and *D*, covering a wide range of assumptions as to the cost per pound of the pipe line in place and the value or cost of the energy sacrificed in frictional resistance. Two of these, *A* and *B*, are plotted from Columns 8 and 9 of Table 1. The figures for *C* and *D* are also readily deduced from the data in Table 1.

A common scale is used for the axes of X and Y. Those points on each curve which satisfy the requirements of $X + Y =$ a minimum will be found in the diagram to coincide with the points of tangency with right lines drawn at an angle of 45° with both

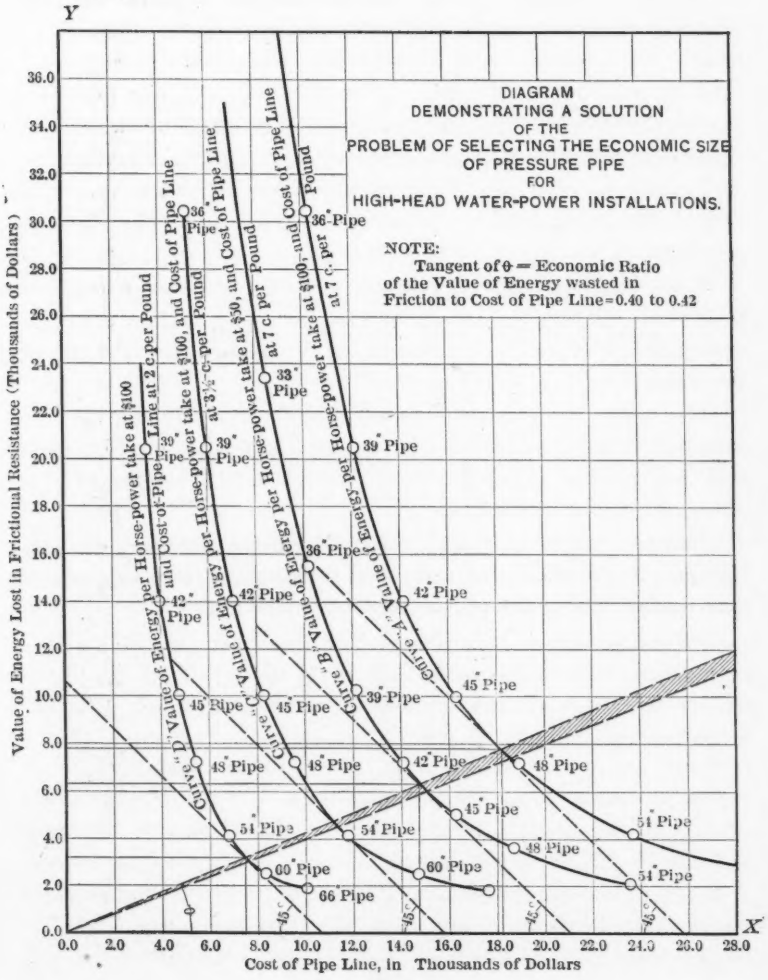

Y
X
DIAGRAM
DEMONSTRATING A SOLUTION
OF THE
PROBLEM OF SELECTING THE ECONOMIC SIZE
OF PRESSURE PIPE
FOR
HIGH-HEAD WATER-POWER INSTALLATIONS.
NOTE:
Tangent of θ = Economic Ratio
of the Value of Energy wasted in
Friction to Cost of Pipe Line = 0.40 to 0.42
Curve "D" Value of Energy per Horse-power take at $100 Line at 2 c per Pound and Cost of Pipe Line
Curve "C" Value of Energy per Horse-power take at $100, and Cost of Pipe Line at 3½ c. per Pound
Curve "B" Value of Energy per Horse-power take at $50, and Cost of Pipe Line at 7 c per Pound
Curve "A" Value of Energy per Horse-power take at $100, and Cost of Pipe Line at 7 c. per Pound
Value of Energy Lost in Frictional Resistance (Thousands of Dollars)
Cost of Pipe Line, in Thousands of Dollars
36" Pipe
39" Pipe
42" Pipe
45" Pipe
48" Pipe
51" Pipe
54" Pipe
60" Pipe
66" Pipe
θ
45°

Fig. 1.

ordinates, because the values of $X + Y$ increase in either direction therefrom.

Now, it will be observed that these points of tangency for all four curves lie on a common straight line through the origin, from which it follows that the tangent of the angle, θ, expresses the economic ratio between the value of the energy sacrificed in friction and the cost of the pipe line; and this ratio is a constant whatever may be the unit values of either of these functions. Graphically, it is not possible to ascertain the mathematically exact value of tan. θ; practically, it is not necessary. It is from 0.40 to 0.42, and for convenience of memory may be stated as the former.

Since, in financial management, annual cost bears a constant percentage relation to capitalized cost, the value of tan. θ will be unchanged, as stated at the beginning, by using either the one or the other.

The writer, therefore, would submit as the rule defining the true economic relation to be observed in designing pipes for high-pressure water-power installations the following, the volume of discharge, of course, being fixed:

That pipe fulfills the requirements of greatest economy wherein the value of the energy annually lost in frictional resistance equals four-tenths (0.4) of the annual cost of the pipe line.

The writer regrets that, having long since lost possession of his calculus, he finds himself unable to verify the rule mathematically, but he hopes someone able to do so will feel interest enough in the subject to undertake it.

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PAPERS AND DISCUSSIONS.

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A DESCRIPTION OF THE RECENTLY INSTALLED SEWAGE DISPOSAL WORKS FOR THE VILLAGE OF BALLSTON SPA, NEW YORK.

By G. L. Robinson, Assoc. M. Am. Soc. C. E.

To be Presented September 18th, 1907.

The plans and specifications for the Ballston Spa sewage disposal plant were prepared by John M. Farley, M. Am. Soc. C. E., and the writer acted as assistant in the design.

Ballston Spa is in Saratoga County, N. Y., on the Kayaderosseras Creek, which flows eastward through the adjoining farming country for about 4 miles and empties into Saratoga Lake. The average population is about 6 000, although during the summer it is much larger. Besides the usual stores and other business buildings common to a country town, there are a number of manufactories of considerable size and output. Among these are the American Hide and Leather Company's tannery, the Union Bag and Paper Company's Island Mill, and the Glen Sulphite Pulp Mill.

The Kayaderosseras Creek, being the natural drainage stream for the village, has received all the products that have passed through the sewers, the tannery alone sending down to the creek, through an arm thereof, daily between 300 000 and 400 000 gal. of

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sewage of such a nature as to render the creek very unsightly. This, together with the pulp mill wastes and domestic sewage contributions, brought about such a condition of pollution that in March, 1899, Governor Roosevelt, acting on a petition of residents and property owners in the vicinity of Saratoga Lake, who claimed the existence of a nuisance, ordered, under Chapter 661 of the Laws of 1893, that all pollution of the Kayaderosseras Creek be discontinued. Whereupon, the Village of Ballston Spa undertook the investigations which led to the construction of the disposal works herein described.

In the design of these works, the engineers had to keep in mind that the make-up of the estimated 1 000 000 gal. of sewage per day was as follows:

Domestic sewage	500 000 gal.
Tannery wastes	400 000 "
Possible infiltration	100 000 "

The infiltration is high because the new sewer lines make connection with many old private lines which were built as "combined" sewers and without the idea of future treatment. Furthermore, the engineers had to keep in mind that:

1.—The cost to the town must be kept at the minimum, while giving satisfactory results.

2.—The sewage must be treated in such a manner that no objection, legal or otherwise, can be raised because of the discharge of the resulting effluent into the Kayaderosseras Creek.

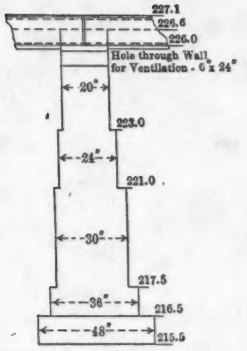
3.—A method must be selected which will remain effective during severe winter weather.

4.—The plant must not create a nuisance in its own neighborhood.

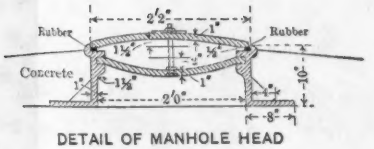
5.—Due regard must be given to the future growth of the town.

To determine the exact nature of the sewage, both tannery wastes and domestic, the engineer recommended that the Board of Trustees retain Dr. Leonard P. Kinnicutt, of the Worcester Polytechnic Institute, to analyze the samples taken. Table 1 shows his analyses.

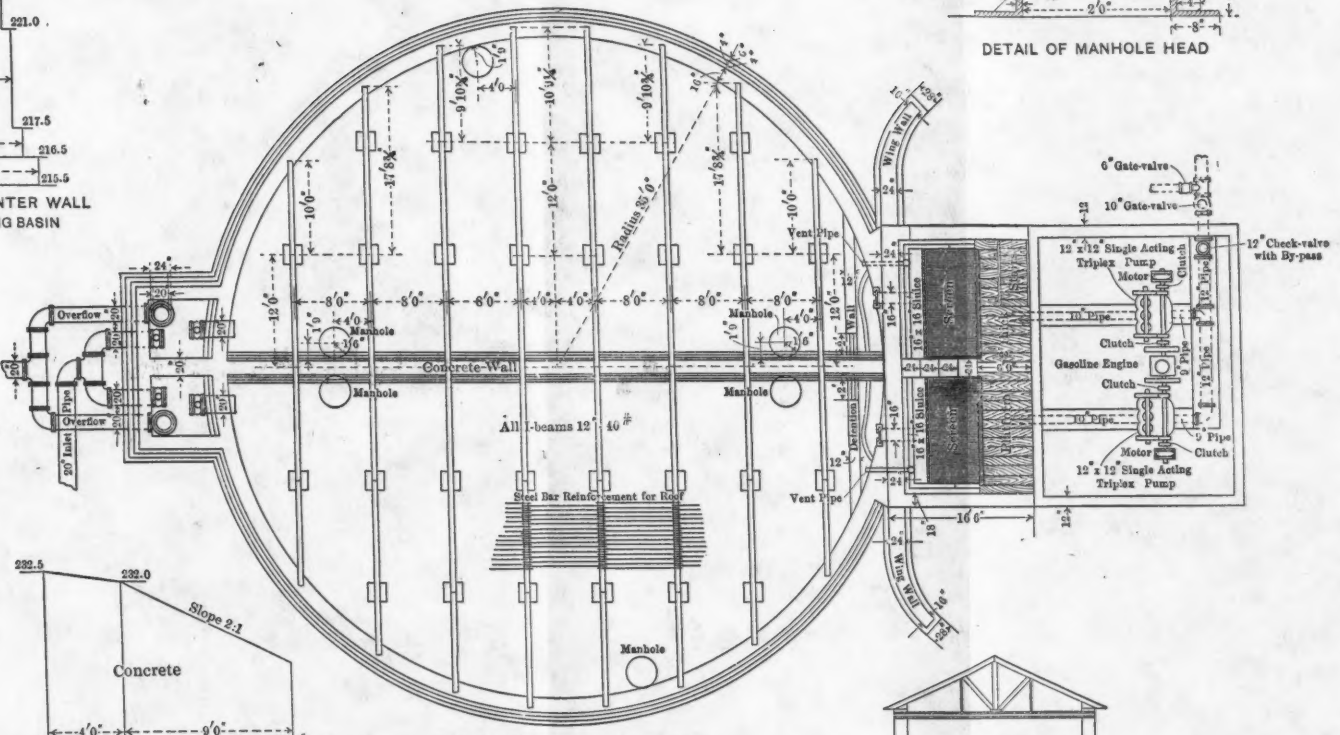
PLAN AND ELEVATION
PUMPING STATION AND RECEIVING TANK
BALLSTON, N. Y.



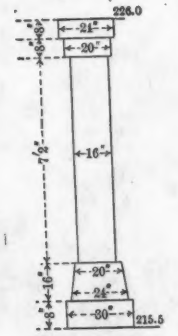
DETAIL OF CENTER WALL OF RECEIVING BASIN



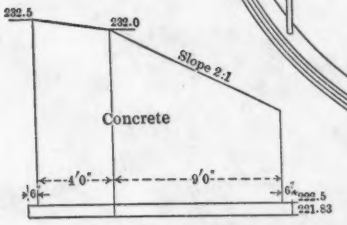
DETAIL OF MANHOLE HEAD



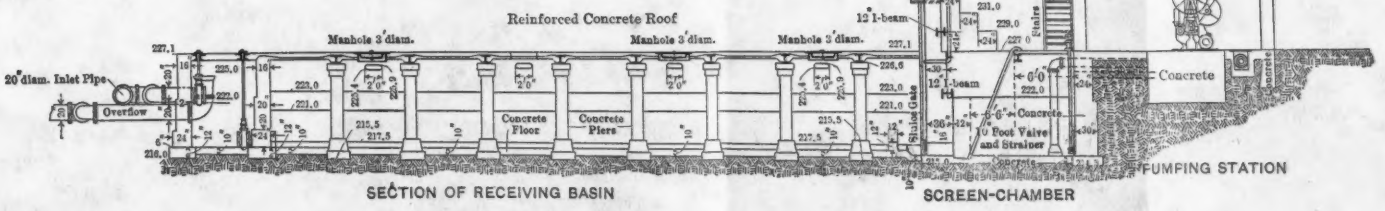
PLAN OF RECEIVING BASIN



DETAIL OF CONCRETE PIERS



DETAIL OF WING-WALL



SECTION OF RECEIVING BASIN

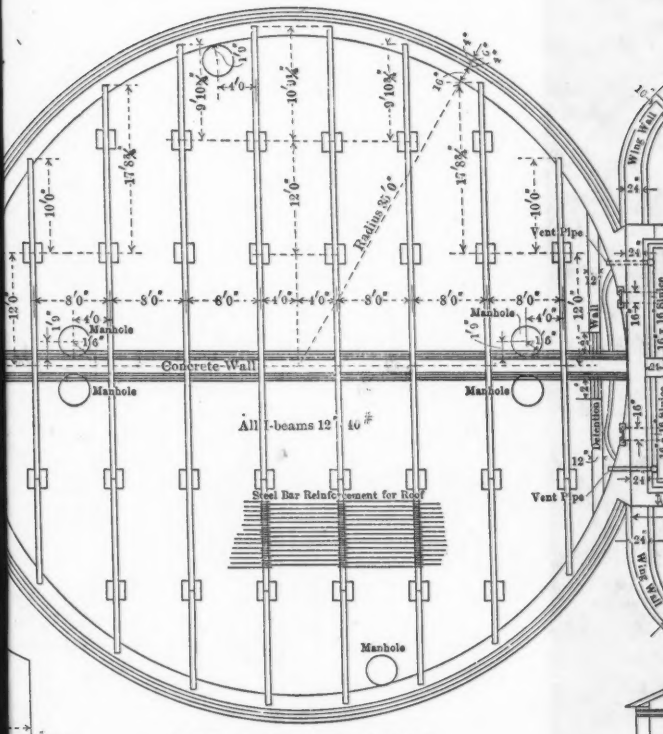
SCREEN-CHAMBER

PUMPING STATION

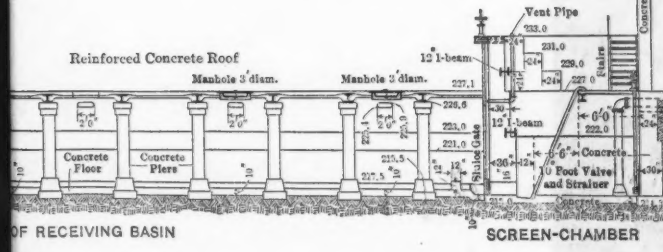
PLAN AND ELEVATION

PUMPING STATION AND RECEIVING TANK

BALLSTON, N. Y.



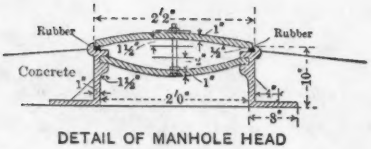
PLAN OF RECEIVING BASIN



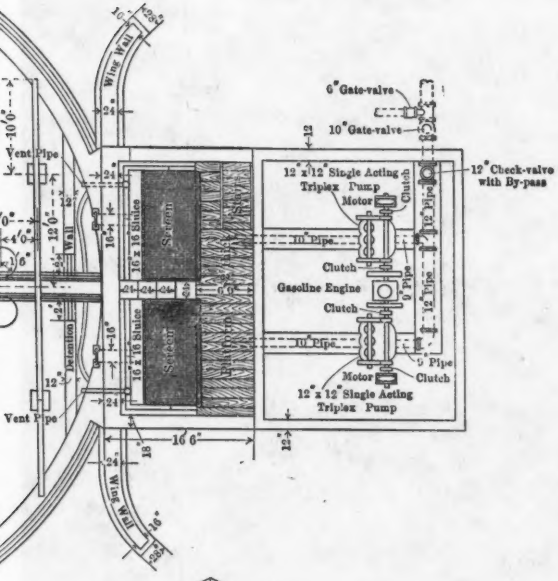
OF RECEIVING BASIN

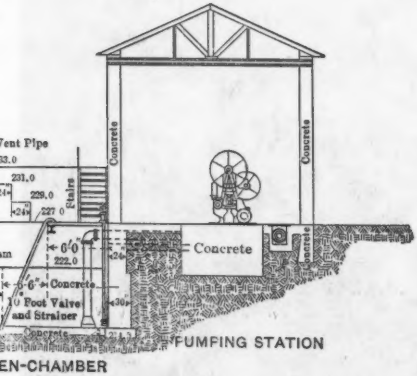
SCREEN-CHAMBER

PLATE LIV.
PAPERS, AM. SOC. C. E.
MAY, 1907.
ROBINSON ON
SEWAGE DISPOSAL WORKS.



DETAIL OF MANHOLE HEAD





PUMPING STATION

EN-CHAMBER

TABLE 1.—ANALYSES OF SEWAGE SAMPLES.

(In parts per 100 000.)

	Domestic sewage.	Tannery sewage.
Turbidity	Marked	Marked
Residue, total	18.0	584.2
" dissolved	14.5	379.2
" suspended	3.5	205.0
" volatile, total	8.8	205.8
" " dissolved	5.5	84.4
" " suspended	3.3	121.4
" fixed, total	9.2	378.4
" " dissolved	9.0	294.8
" " suspended	0.2	83.6
Ammonia, free	0.32	2.62
" albuminoid, total	0.284	4.594
" " dissolved	.....	.....
" " suspended	.....	.....
Chlorine	1.75	120.58

As the study of the problem progressed further, it was deemed advisable to determine the influence of the tannery wastes in combination with the domestic sewage, from chemical and bacteriological points of view, and Harrison P. Eddy, M. Am. Soc. C. E., was retained, and reported the results given in Table 2.

TABLE 2.—STUDIES IN RELATION TO THE SEPTIC PROPERTIES OF TANNERY WASTE FROM BALLSTON SPA, N. Y., AUGUST 14TH, 1905.

Total Number of Bacteria Cultures in 1cc.

*Sample.	July 29th.	July 31st.	August 2d.	August 5th.	August 8th.
S	8 000 000	8 000 000	10 000 000	320 000 000	36 000 000
W	Liquefied.	700	47 200	2 445 000	232 600 000
W + *S*	.....	19 200	3 135 000	27 840 000	1 801 500 000

Free ammonia in fresh sample and after standing; results in parts per 100 000:
W, July 29th = 3.10; *W*, Aug. 5th = 5.10.
Alkalinity, in terms of CaO in 100 cc.:
W = 0.0693 gram.
* Description of samples:
S = Sample of domestic sewage from Tatman Street sewer;
W = Tannery waste.

These samples represented about the mixture that would have to be treated by the disposal plant. Mr. Eddy found an increase in the number of bacteria per cubic centimeter and a great increase in the mixture. The free ammonia was the same in each sample, which would tend to show that the tannery product was only slightly antiseptic, if at all; and, furthermore, the mixture with domestic

sewage in the ratio of 1 to 1, or more, really caused a greater bacterial activity in breaking down the organic matter.

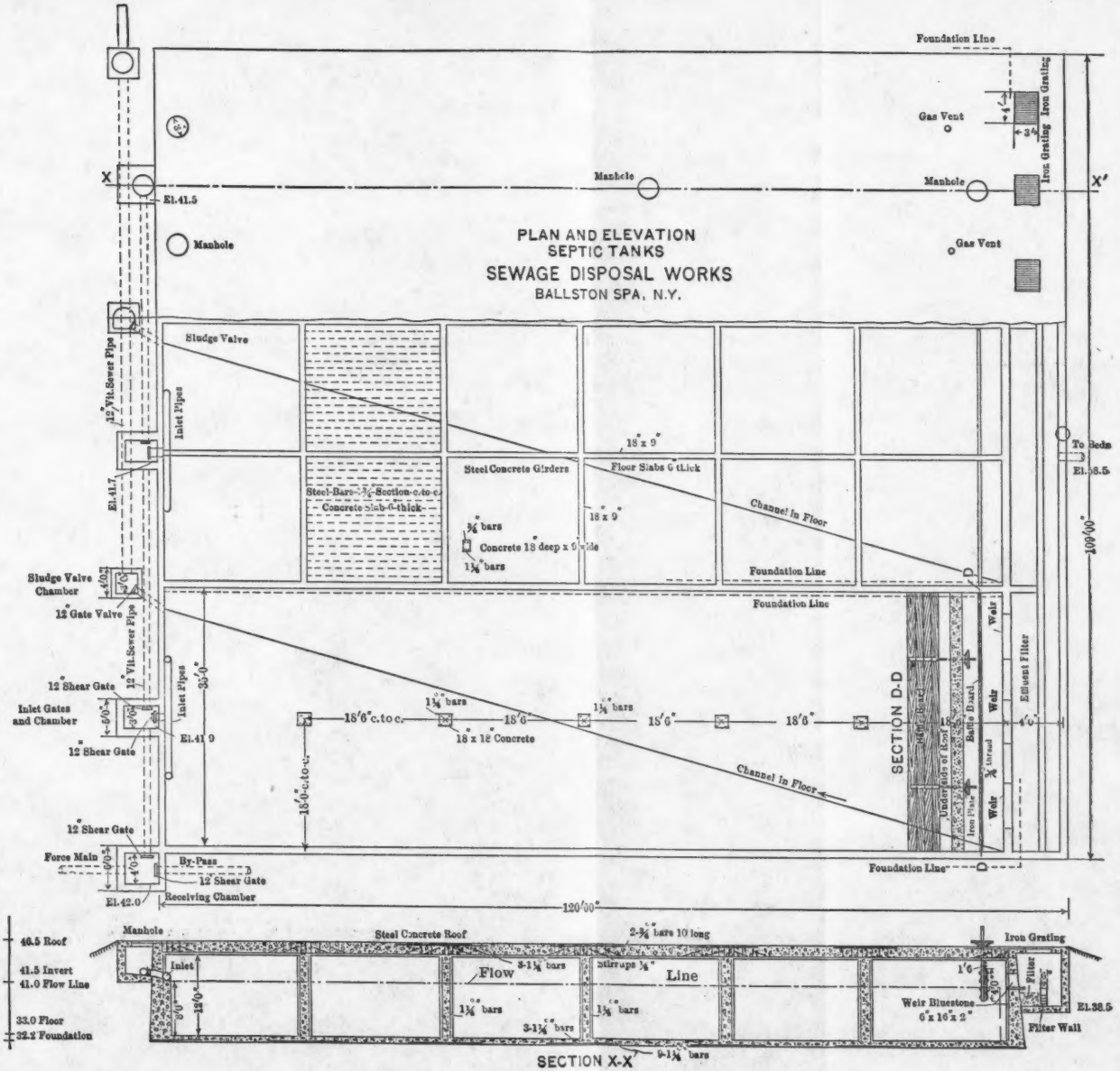
The tannery waste is the liquid waste which results from the treatment of hides, being lime water neutralized by lactic acid. It also contains the red liquid product made by passing water over ground hemlock bark.

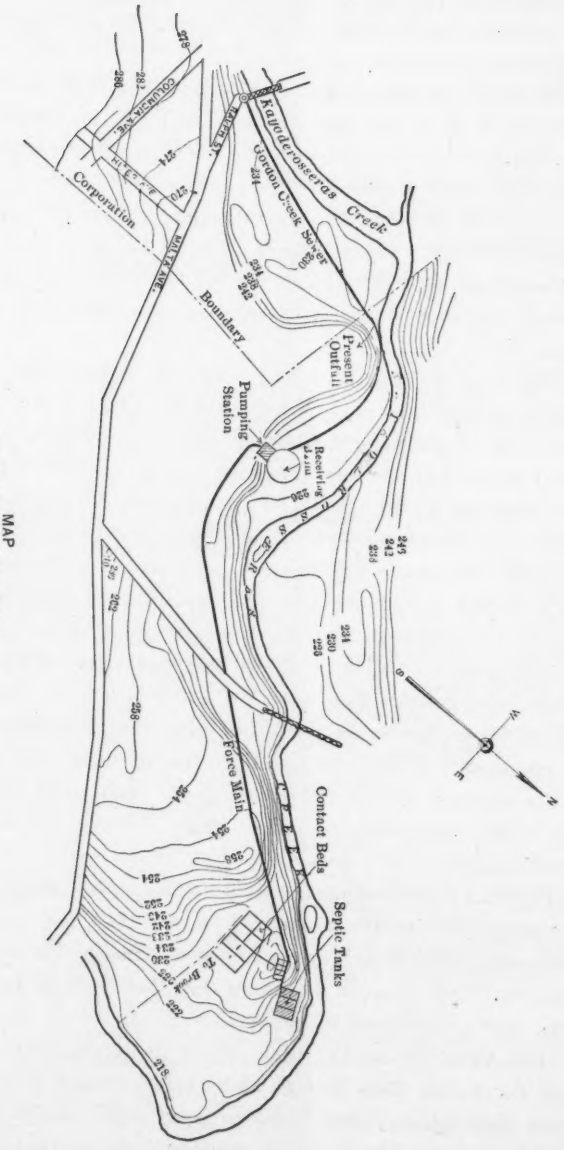
The minimum daily flow of Kayaderosseras Creek is said to be 30 000 000 gal., and, as the State Board of Health set no standard of purification to be reached, it was thought that the works should be planned to produce an effluent which would be non-putrescible and would quickly mix with the creek water and be ultimately purified.

The disposal plant consists of the receiving tanks, the pumping outfit, a 12-in. cast-iron force main, septic tanks, and double contact beds, as shown in Fig. 1.

The sewage is delivered to the receiving tank, or well, by an extension of the 20-in. Gordon Creek sewer, which has a by-pass directly into the creek about 1 100 ft. above the receiving tank. The receiving tank is on flat gravelly ground about 150 ft. from the creek, and at a point where the roof of the tank may be submerged in times of high water. The tank is of reinforced concrete construction, as shown by Plate LIV, 70 ft. in diameter and 9 ft. deep, and when full will contain 259 000 gal., or 25% of the day's flow. It is divided into two equal compartments by a solid concrete wall, 36 in. thick at the base and 20 in. thick at the top, and extending from floor to roof. This wall also subdivides the gate-chamber. Just outside the inlet gate-chamber the 20-in. vitrified pipe sewer changes to a flanged cast-iron pipe, and is divided into two 20-in. pipes. These lead into the gate-chamber, one into either compartment, and each is provided with a 20-in., bronze-mounted shear-gate.

From these chambers two flanged cast-iron pipes lead into the receiving basin, and are each provided with 20-in. gates, whereby the sewage may be turned into either or both compartments. From here it passes through two 16 by 16-in. openings, provided with sluice-gates, into the suction-chamber, from which it is delivered by pumps through the 12-in. force main, 2 700 ft. long, to the septic tanks and contact beds.


PLAN AND ELEVATION
SEPTIC TANKS
SEWAGE DISPOSAL WORKS
BALLSTON SPA, N.Y.
Foundation Line
Gas Vent
Iron Grating
Manhole
X
X'
El. 41.5
Sludge Valve
12" Vit. Sewer Pipe
Inlet Pipes
El. 41.7
18" x 9"
Steel Concrete Girders
Floor Slabs 6" thick
Steel Bars 3/4" Section c. to c.
Concrete Slab 6" thick
3/4" bars
Concrete 18" deep x 9" wide
1 1/4" bars
To Beds
El. 38.5
100'0"
Channel in Floor
Sludge Valve Chamber
12" Gate Valve
12" Shear Gate
Inlet Gates and Chamber
El. 41.9
35'0"
18'6" c. to c.
18" x 18" Concrete
15'0"
SECTION D-D
Weir
Effluent Filter
Baffle Board
Iron Plate
Force Main
By-Pass
Receiving Chamber
El. 42.0
120'00"
46.5 Roof
41.5 Invert
41.0 Flow Line
33.0 Floor
32.2 Foundation
Steel Concrete Roof
2-3/4" bars 10' long
Inlet
Flow Line
3-1 1/4" bars
Stirrups 1/4"
1 1/4" bars
Weir Bluestone 6" x 16" x 2"
Filter Wall
SECTION X-X



MAP
SHOWING THE LOCATION
OF
PROPOSED DISPOSAL WORKS FEATURES
BALLSTON SPA, N.Y.

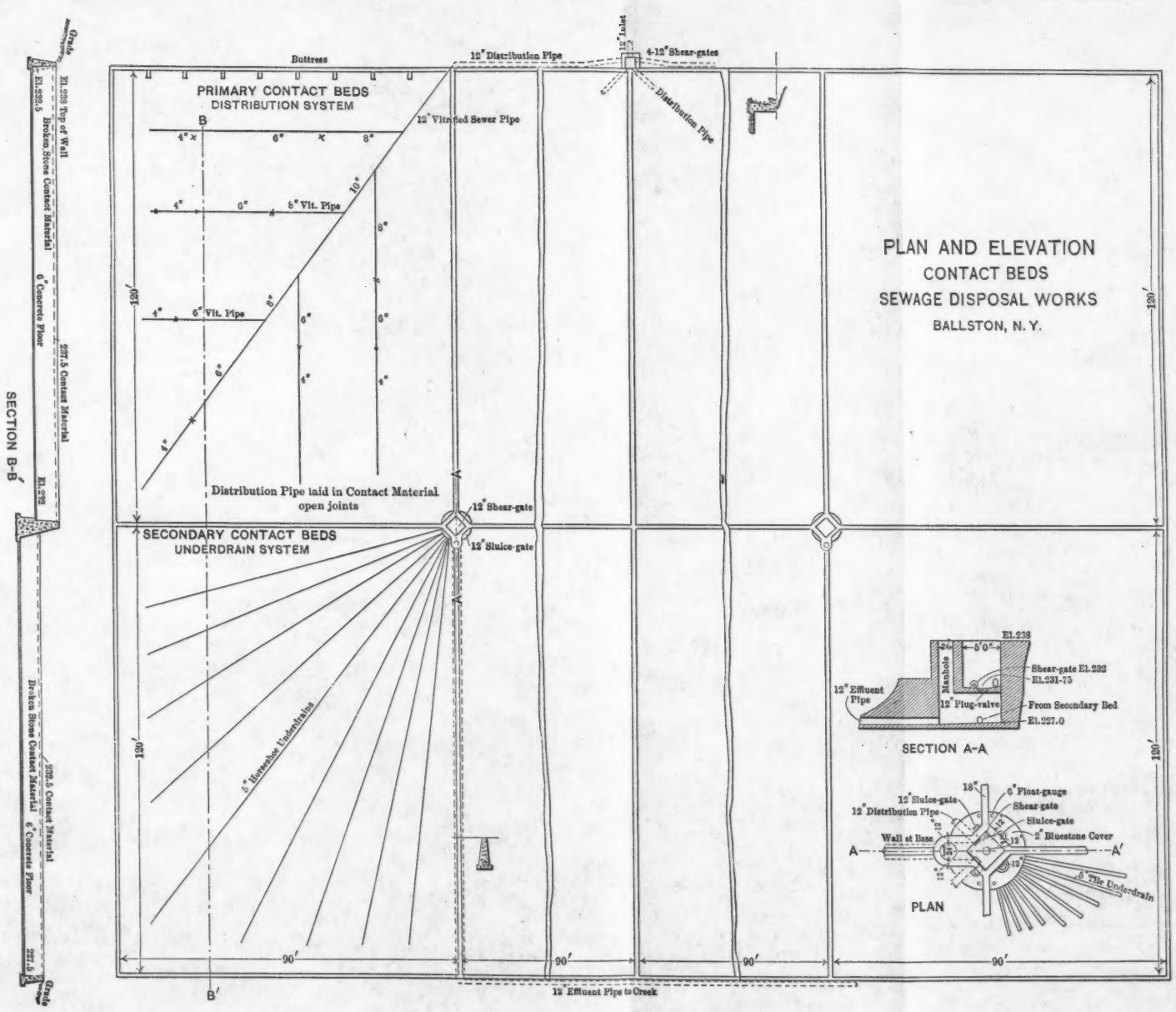
Fig. 1.

The receiving tank is subdivided, to facilitate cleaning. By this arrangement all the sewage may be turned into one side, while the other is cut off, emptied, and cleaned. Each compartment of the gate-chamber is provided with a 20-in. flanged overflow pipe. The depth of the sewage in the receiving tank is 8 ft. at the inlet end, and 8 ft. 6 in. at the outlet end. The floor has a slope of 6 in. in its length along the center wall. At the outlet end of each compartment, directly in front of the sluice-gates, there is a wall 12 in. high which prevents the very heavy matter from entering the suction-chamber. The suction pipe is protected still further by intercepting screens erected across the suction-chamber. These screens are kept clean with rakes manipulated from the platform above.

The roof of this tank is of special construction, designed to uphold a dead load of 1 ft. of earth covering, and 5 ft. of water. The walls of the pumping station have been brought up solid 6 ft. above the roof of the receiving tank and made perfectly water-tight. The pumping outfit consists of two Rumsey, single-acting, outside-guided and outside-packed, 12 by 14-in., plunger pumps, with bronze plungers and bronze ball-valves. Each pump is connected by gearing to a 25-h. p., 600-rev. per min., 220-volt, 40-cycle, General Electric motor, geared to give the pumps a speed of 34 rev. per min., or each pump a capacity of 800 gal. per min. Between the two pumps, and connected to each by a friction-clutch coupling, there is a 25-h. p. Fairbanks-Morse gasoline engine, which is installed for emergency power, and is only intended to be used in the event of the stoppage of the electric current. The plant is arranged so that either pump can be driven from the engine, or by its own separate motor.

The plan is to pump the sewage to the septic tanks so as to keep a constant flow at the tanks day in and day out. The receiving tanks and pumping well are intended to equalize the flow of sewage from the village in such a manner that there will be no disturbance of the septic conditions in the tanks.

It is seen that at the very outset the conditions are unusual. First, the sewage flows through about half a mile of 20-in. sewer with a very light grade, where some primary septic action is being developed. Second, it is held in a receiving tank or sump for a period


PRIMARY CONTACT BEDS
DISTRIBUTION SYSTEM
SECONDARY CONTACT BEDS
UNDERDRAIN SYSTEM
Buttress
12" Distribution Pipe
4-12" Shear-gates
Inlet
Distribution Pipe
12" Vitrified Sewer Pipe
6" Vit. Pipe
Distribution Pipe laid in Contact Material open joints
12" Shear-gate
12" Sluice-gate
6" Horseshoe Underdrains
12" Effluent Pipe to Creek
90'
120'
PLAN AND ELEVATION
CONTACT BEDS
SEWAGE DISPOSAL WORKS
BALLSTON, N. Y.
SECTION A-A
Manhole
Shear-gate El. 232
El. 231.75
12" Effluent Pipe
12" Plug-valve
From Secondary Bed
El. 227.0
PLAN
6" Float-gauge
Shear-gate
2" Bluestone Cover
6" Tile Underdrain
Wall at Base
SECTION B-B'
Grade
El. 239 Top of Wall
El. 232.5
Broken Stone Contact Material
6" Concrete Floor
227.5 Contact Material
El. 232
232.5 Contact Material
227.5

of from 3 to 6 hours, depending upon the use of the full capacity or only half the capacity of the sump. Third, there is a severe mechanical breaking up of the organic matter by the action of the pumps in lifting it to the septic tanks.

The septic tanks (Plate LV) are on the top of a small hill, and placed so that the effluent therefrom can pass by gravity through the double sets of contact beds, and underdrain back into the creek. Sludge draw-off pipes are provided to take the sludge to beds prepared for that purpose.

The 12-in. cast-iron force main delivers into a by-pass chamber which is a concrete manhole 4 ft. square and 5 ft. deep. From this chamber are led the 12-in. pipe which supplies the septic tanks, and the 12-in. by-pass sewer which passes around the works and connects with the final underdrain to the brook beyond.

There are three septic tanks, and they are arranged so that they may be placed in operation singly, or in sets of two, or all at the same time. Each tank proper is 111 ft. long, 35 ft. wide, 8 ft. deep at the inlet end, and 7 ft. deep at the outlet end, measured from the flow line, and each holds approximately 218 000 gal., or about 22% of the estimated daily flow, and would give a tank period of a little more than 5 hours if only one unit at a time were in use; but, counting the action in the pump-well as 3 hours, the minimum period for septic action is about 8 hours; and when all three units are in use at the same time, with the pump-well full, the maximum period for septic action is about 24 hours. Hence, in operating the plant, there will be a considerable range through which to try the effect of rates of retention.

After leaving the by-pass chamber, the sewage passes through the 12-in. pipe to the three gate-chambers, one at the head of each septic tank. These chambers are 3 by 4 ft. in plan, and about 5 ft. deep. In them are set two 12-in. bronze-mounted shear-gates to permit the flow to enter each tank, or pass on to the next. The sewage enters each tank by two 12-in. bends of terra cotta pipe, brought down 3 ft. below the flow line. The pipe is supported by the end wall of the tank. The floor has a slope of 1 ft. from the outlet end to the inlet end, and is channeled diagonally the full length. At the end of the channel a 12-in. sludge-pipe leaves the tank and enters the sludge-valve chamber which is approximately 3 ft.

square and the full depth of the tank. In this chamber is set a 12-in. bronze-mounted gate-valve arranged so that, when it is necessary to remove the scum or sludge from the tanks, the opening of the gate will pass this matter out through a 12-in. sludge-sewer to the sludge-beds beyond, where it can be composted or plowed under.

In each septic tank, 3 ft. from the outlet end, is a timber baffle wall, extending from side to side of the tank. It can be raised or lowered by wheel screws fixed on the roof of the tank. The idea in this is to permit the adjustment of the opening beneath the baffle so as to prevent undue currents. After passing under this baffle, the effluent leaves each tank over three weirs in the end wall. Each weir opening is 6 ft. long, and has a space in the wall 2 ft. high. The weir itself is of bluestone, 18 in. wide and 2 in. thick, built into the concrete with a slope of 1 in. outward. The effluent falls from the weirs upon a coke breeze filter, the particles of which have a diameter not greater than ½ in. The filter is 2 ft. deep and 2 ft. wide and extends the entire width of each tank. The filter material is held in place by an 8-in. hollow brick wall. This arrangement is set in a filter chamber 5½ ft. wide and extending the full width of all three tanks. The main tank roof extends over this portion, and in it 4 by 3-ft. open gratings are set. Each tank has three of these openings.

The effluent, after passing the filter, flows to the center of the filter chamber and leaves by a 12-in. pipe, passing to the contact beds beyond. It is thought that by this bed the suspended particles of the bacterial mat formation, which occasionally break loose and pass out of septic tanks, will be arrested on the coke, and that the coke may be renewed from time to time, thereby, to a great extent, protecting the contact beds from clogging. Furthermore, it acts as an aerator, and starts the oxidation of the effluent. It is hoped that the life of the contact beds will be very long, and that it will be necessary to clean them only at very long intervals.

The septic tanks and gate-chambers (Plate LVI) are of reinforced concrete, in which the Kahn system of trussed bars is used. The thickness of the walls is 2 ft. at the base and 1 ft. at the top. They rest on a footing 1 ft. thick and 1 ft. wider than the wall. The total depth at the inlet end, from the underside of the roof to the top of the finished floor, is 12 ft., and at the outlet end is 11 ft. The thickness of the floor is 8 in. and of the roof 6 in.



FIG. 1.—PUMPING SUMP.

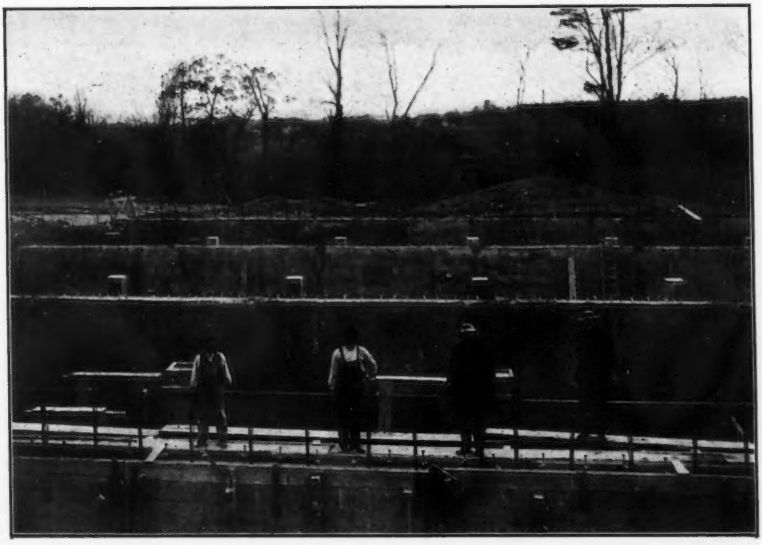


FIG. 2.—SEPTIC TANKS.

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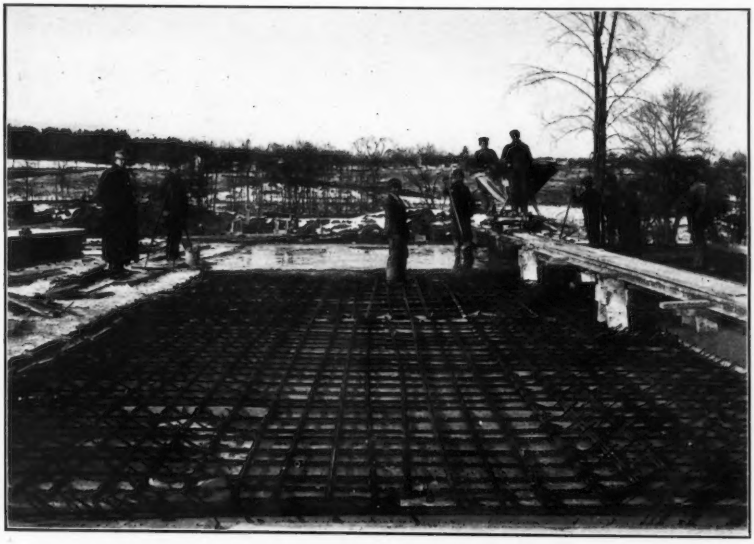


FIG. 1.—ROOF REINFORCEMENT.

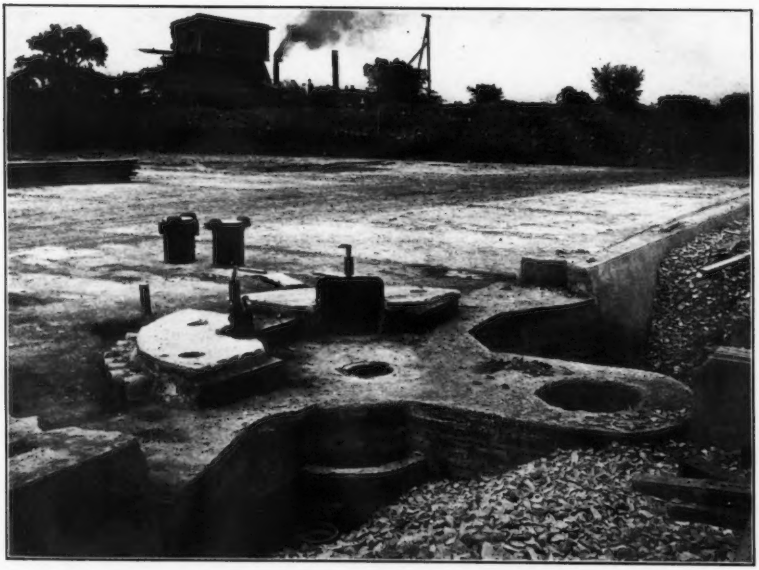


FIG. 2.—UNDERDRAIN GATES.

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The roof is supported down the center of each tank by five columns, 2 ft. square, and 18 ft. 6 in. from center to center lengthwise of the tank, and 18 ft. from center to center across the tank. The roof over each tank contains four manhole openings, 3 ft. in diameter, and is ventilated by two 6-in. openings for gases.

There are four primary and four secondary contact beds at high and low level. The effluent from the tanks flows directly to the gate-chamber of the contact beds through a 12-in. vitrified pipe sewer. This gate-chamber is 4 ft. square, has 12-in. walls, and in it are set four bronze-mounted shear-gates which control the flow of sewage to either of the four primary contact beds. The beds are each 120 ft. long, 90 ft. wide, and 6 ft. deep, from the top of the finished wall to the top of the finished floor. The walls are of concrete, 1 ft. thick at the top and 2 ft. thick at the bottom, built on a footing 1 ft. thick and 3 ft. wide. The wall between the primary and secondary beds is 12 ft. high; its thickness is 18 in. at the top and 5 ft. at the bottom, and it is built upon a footing 1 ft. thick and 7 ft. wide. This wall resists the thrust of the contact material of the primary bed, and the natural earth upon which it is built. All the floors of the beds are 6 in. thick. The contact material is broken field stone, or hard-heads, and is mostly of a hard and crystalline character like granite; it has made a most uniform material throughout, both as to hardness and color.

The specifications for contact material called for 1½, 2, and 3-in. broken stone of such a character as to resist disintegration by the action of the elements. This same broken stone, but of "½ to 1 in. least diameter, and not exceeded by more than 50%" was used as concrete material. The contact material fills the beds to within 6 in. of the top of the walls, giving a depth of 5½ ft. The distribution of the sewage is brought about by a system of 12, 10, 8, 6, and 4-in. vitrified pipe distributors laid in the top of the contact material. The larger pipes act as mains, and the lesser pipes as branches therefrom at angles of 45 degrees.

The contact material is graded, the coarse being at the bottom and the fine at the top. The lower 18 in. contains 2 and 3-in. broken stone; the next 3 ft. contains 1½-in. stone, and the upper layer is of 2-in. stone. In each bed there is a series of nine lines of 5-in. horseshoe-tile underdrains, laid on the finished concrete

floor and radiating toward the center, at which is the gate-house. There is a gate-chamber and house in the center of each group of four beds (two primary and two secondary), in which are the gates and valves which control the emptying of the primary, and the emptying and filling of the secondary beds. There is first an upper compartment into which the underdrains of the primary beds deliver. This is 3½ ft. square and 6 ft. deep, from the top of the wall of the upper bed. Outside of this chamber, in the two upper beds, are bluestone covers which receive the tile underdrains. Back of this, and against the wall of the gate-chamber, is set a 12-in. sluice-gate at the level of the floor of the primary bed. This is controlled by a spindle and wheel screw operated from the floor of the gate-house above. There is a float-gauge at this point, with an indicator in the gate-house to show the level of the sewage in the bed. There is a 12-in. plug-valve in the bottom of the chamber, which connects directly with the 12-in. effluent pipe leading to the creek. The secondary beds are controlled by two 12-in. shear-gates inside the gate-chamber, and two 12-in. gate-valves in the well beneath, level with the floor of the secondary beds. Each gate-chamber is covered by a handsome red brick gate-house with a red tile roof. This structure protects the wheels and lever handles of the several gates and valves.

It is estimated that each bed will hold 130 000 gal. of sewage independent of the contact material, and have an ample allowance for the ultimate partial filling of the voids due to undecomposed sewage particles retained therein. The beds may be worked in a number of combinations, and with various periods of retention. It is proposed to use them in cycles as follows:

Assuming that sewage is first turned into Bed No. 1 at 12 c'clock, midnight, this bed will fill for 2 hours, stand for 2 hours, and empty for 2 hours into Bed No. 1 of the secondary set. Bed No. 2 of the primary set begins to fill at 2 A. M., Bed No. 3, at 4 A. M., Bed No. 4, at 6 A. M., and Bed No. 1 begins to refill at 8 A. M.

The secondary set follows the primary set. The sewage is in contact in passing through the beds from midnight until 8 A. M., that is, that which enters Bed No. 1 (primary set), between midnight and 2 A. M., leaves Bed No. 1 (secondary set), between 8 and 10 A. M.

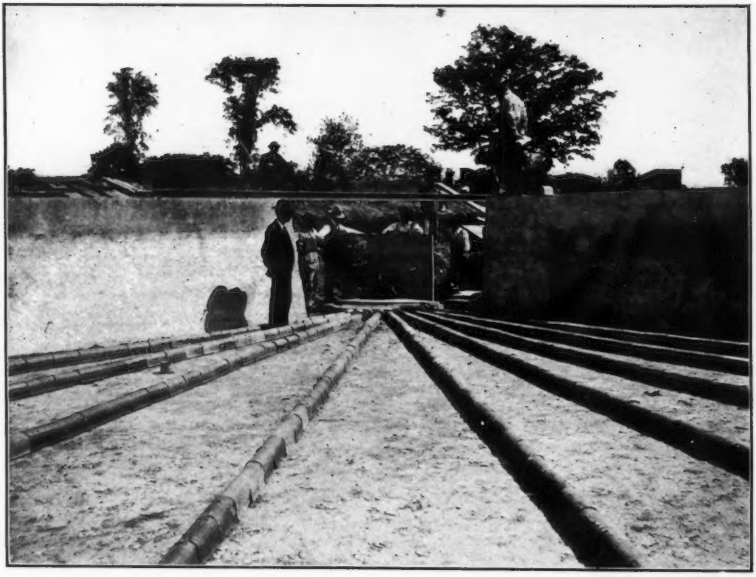


FIG. 1.—TILE UNDERDRAINS.

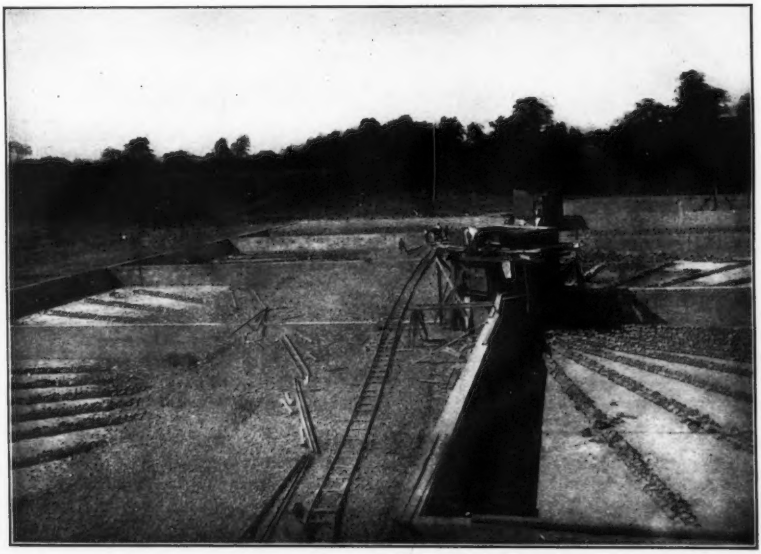


FIG. 2.—PLACING CONTACT MATERIAL.



FIG. 1.—SECONDARY BEDS.

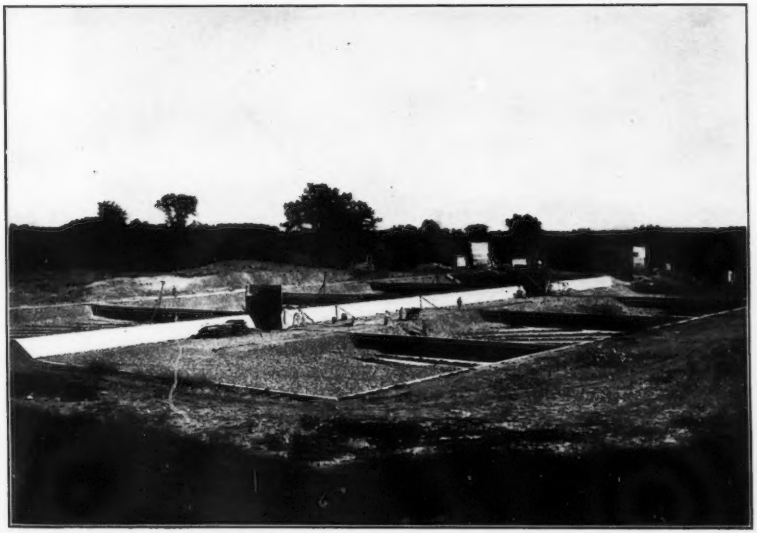


FIG. 2.—PRIMARY AND SECONDARY BEDS.

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The cost of the work, as shown by the accepted bid, was as follows:

Septic tanks, beds, etc	$39 456
Receiving tank, pumping outfit	15 254
Pump-house	3 072
Two gate-houses	1 118
Force main ($1.68 per ft.)	4 536
Sewer extension ($1.41 per ft.)	1 551
Crushed stone ($0.90 per cu. yd.)	18 000
Total	$82 987

The contractors were Messrs. Brown and Lowe, of Schenectady, N. Y.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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THE LOWER COLORADO RIVER AND THE SALTON BASIN.

Discussion.*

By Messrs. W. de H. Washington and J. A. Ockerson.

Mr. Washington.

W. de H. Washington, Assoc. M. Am. Soc. C. E.—The speaker recently visited the scene of the break in the Colorado River, and will attempt to describe briefly some of the events which have occurred since the last break described in Mr. Grunsky's able paper, although no adequate idea of the magnitude of the problem can be obtained from any description.

At that time the break was nearly half a mile wide, the velocity of the water in the river was from 3 to 6 miles per hour, and the channels were from 20 to 35 ft. deep.

The material in the river bottom has little or no value as a holding agent. One of the discussors refers to a method of handling materials "as fine as sea sand," but, in comparison with the Colorado River silt, sea sand is almost as coarse as cobble-stones. This silt, when wetted and rubbed between the fingers, gives no feeling of grit, whatever; neither can one hear any sound of grit when holding it close to the ear, and rubbing it in the fingers.

During low water, when the river bottom is dry, one may stand on this material, and it seems to be quite firm, yet, by pressing the foot upon it several times the sensation is that of standing upon a mattress resting upon water. It feels as though that slight pressure of the foot had made the soil beneath as fluid as water. The surface or top covering, however, may be removed, and no water

*Continued from April, 1907, *Proceedings*.

will be seen, only wet mud which, apparently, has not enough sustaining power to support one's finger. Mr. Washington.

The silt in the river bottom, when dry, almost invariably cracks in the form of pentagonal prisms. From above, its appearance is not unlike the peculiar formation at the Giant's Causeway. The cracks are so large that one's hand may be thrust into them, and so deep that one cannot see the bottom. It might be thought that one could walk and stand upon this cracked and baked soil, but it is treacherous; the speaker tried it, and sank almost to the hips. The surface may be dry for a foot or two, but there is no sustaining power below that. This material will not expand again if water is placed on it, but will simply remain in that form, the angular parts only melting and filling the interstices. It has very little consistency, and if any water comes in contact with it (even the 3 ft. of head mentioned in the paper), it will find its way through it, so that unless the silt is entirely removed from under a levee before its construction, the water is likely to wash it out. Without doubt, this material is composed of exceedingly fine alkali dust carried down by the river from that vast region between the Sierra Nevadas and the Rockies. The Colorado is very seldom clear, but carries from 2 to as much as 7% of suspended matter, and the fact that such a large percentage of this material is carried in suspension for so great a distance gives some idea of its extreme fineness.

Like the Mississippi and the Nile, the Colorado has built up its bed until it is practically running in a channel above the level of the surrounding country on both sides; consequently, any break in the bank gives it an opportunity to rush away with a rapid current. Breaks in the Mississippi levees are readily closed because the slope of the land away from the river is not great enough to cause much current across the country; and there is no channel cutting, as the bottoms are usually level, and the water spreads and soon begins to back up.

Away from the banks of the Colorado, however, there is a slope of about 5 ft. per mile, and the scouring action of such a river in such material is very great. Down in the desert a fall of about 70 ft. has been formed by the back-cut of the river; in fact, it has back-cut in the same way as the Niagara. There is little doubt that Niagara Falls were at one time as far down as Lewiston, at the foot of the gorge. This can easily be understood by examining the gorge; and it is known that, from year to year, the falls are gradually receding toward Buffalo.

When the total flow of the Colorado was diverted from the old into the new channel, the old channel was left dry. The greatest river flow is about 120 000 cu. ft. per sec., and this was the volume

Mr. Washington.

of water with which the engineers had to cope. The rises in the river are uncertain on account of the water-spouts or cloudbursts on the water-shed of the Gila River, which enters only 12 miles above Yuma. Frequently, within 24 hours, this river pours down as much water as the maximum flow of the Colorado. The periods of greater flow in the Colorado are between May 15th and August 15th; but the Gila is likely to rise at any time.

In repairing the break, practically all methods proven by the best previous practice were tried. Brush mattresses, about 18 in. in thickness, were put in, and more than 40 miles of cable, 2 000 cords of brush, and 1 100 piles were used, but neither mattresses nor anything else which could be placed upon that mud would hold, because the slightest current caused scour beneath the mattresses.

Finally, three parallel trestles, about 30 ft. apart, were built across the break, and from them were dumped the largest stones obtainable, some of which weighed as much as 6 tons. Such stones, lying upon the silt, had sufficient weight to prevent the water from undercutting, and held the silt until more stones could be put in.

Fortunately, several hundred cars, used in making the Lucian cut-off across Great Salt Lake, were at the disposal of the Southern Pacific Railroad. Most of these were 50-ton, side-dump, ballast cars, facetiously called "battleships." These were loaded with stone and brought down in trains of 40 or 50 cars. These cars were unloaded almost simultaneously on the trestles, and thus a cascade dam was made, with the large rocks below and the smaller ones on top. Of course, such a dam was permeable, but the rocks on the bottom held the silt until a tighter dam could be raised. Finally, when the flow was turned back into the old channel, the face of the dam was filled in with gravel, then with clay, and then, to make it water-tight, silt was pumped on it.

It is not thought that one trestle, or even two, would have been sufficient to make the closure, as the third was needed as a reinforcement. Some of the piles in the trestles were nearly 100 ft. long, many of them were 65 ft., and yet, during the last rise, the scouring power of the river was so great that many of these piles were undermined and shot up through the water and floated away. In the last closure of the break, water tanks were placed on some of the trestle bents and filled with water to keep them down and steady them.

The credit for handling this difficult work in such a masterly way should be given to Epes Randolph, Vice-President of the Southern Pacific Railroad, and his able assistant, H. T. Cory, Assoc. M. Am. Soc. C. E., who was in charge of the work. The organization of men, teams, and material, and the railway transportation were almost perfect, and it should be remembered that the camp had to

be created in a desert, and that more than half the laborers were Indians. Mr. Washington.

The greatest danger to be feared, now that the break has been closed, is that some part of the levee may give way.

In a letter received from Mr. Randolph about March 10th, 1907, the following details are given:

"The water was shut off by the application of 77 000 cu. yd. of material, mostly rock, but this did not by any means complete the dam.

"The total yardage dumped into the trestle up to March 1st is something like 130 000 cu. yd., clay and gravel being the principal material applied since the closure of the break. When the dam shall have been completed, it will contain a total of about 140 000 cu. yd., between 85 000 and 90 000 cu. yd. of which will be rock, but all the data will be given you accurately a little later."

The speaker has no doubt that had not this break been in the vicinity of a great railroad, and had not the entire resources of that railroad been at the disposal of the engineers, it would have remained open for years.

The New or Alamo River, in rushing across the country, has cut a channel about 80 miles long, some 1 500 ft. wide, and from 60 to 70 ft. deep. The Panama Canal is to be about 40 miles long, from 150 to 200 ft. wide on the bottom, and approximately 30 ft. deep; therefore the channel cut by the Colorado in a few months is approximately twice as long, nearly ten times as wide, and nearly twice as deep as the Panama Canal will be, and in that time the river has moved many times the yardage that will be required to complete the great interoceanic waterway.

The problem is almost as interesting from a financial standpoint, for the Statistician of the United States Reclamation Service has estimated that, had this break not been closed, the damage which would have been done eventually would have amounted to some $700 000 000.

J. A. Ockerson, M. Am. Soc. C. E. (by letter).—Having made two visits to the scene of the "Colorado break," one just at the beginning of the closure work in August, 1906, and the other shortly after the failure in November of the same year, a few remarks relating thereto may not be amiss. Mr. Ockerson.

The natural ground on which the levee was built is composed of light loose soil, filled with cracks such as are found in silt deposited by overflow, which has afterward dried out. These cracks were filled, to a certain extent, with other light soil, probably drifted in by the winds; to this add roots and fine drift extending down to water level, or even below, and it will be seen that the foundation for a levee was extremely bad.

Mr. Ockerson.

After the break, a length of several hundred feet on both sides of the levee, and down to the water surface, was exposed. Several test-pits were also dug in the borrow-pit for the purpose of studying the cause of the failure. A careful examination of these held out little hope that, on such soil, a permanent levee could be constructed near the flowing river without the addition of sheet-piling below the water line.

The levee itself had little or nothing to do with the failure. The water stood but a short distance above its base at the time of the break; it found its way through the cracks and roots some distance below the base of the levee, and into the bed of the old intake in considerable volume while the levee was still intact. The defects developed over a distance of several hundred feet, and were of such a nature that no "sub-levee" or "hoop" would have availed.

Some attempts were made to stop the flow by dropping in, on the upper side, sacks of earth, brush, and bales of hay, but most of these passed through the "blow-outs" without accomplishing the desired purpose, and, in a short time, the levee itself fell into the chasms which had been washed out beneath it.

It is perhaps well to emphasize one phase of the situation having an important bearing on the failure. The increased slope to the Salton Sea had cut down the bed *via* the artificial intake, so that it was some 12 ft. below the bed of the Colorado River proper. Hence, when the water was diverted to the latter, it was high above the bed of the intake, and the intervening soil, of the character described, readily permitted a very considerable amount of percolation, and doubtless contributed largely to the disaster, as the distance between the two channels was not great.

It has been frequently asked why the old bed of the river, at the intake, is not also cut down by the effect of the current. The old bed was developed by the river itself, and is controlled by the functions of volume and slope, and, without changing these elements, the bed must remain essentially as it is.

That a serious mistake was made in taking the earth from the land side seems evident, but it is altogether probable that the break would have occurred if the borrow-pit had been on the river side of the levee, as the bed of the near intake channel was well below any borrow-pit.

It is said that a small muck ditch was dug near the toe of the levee on the river side, but it was neither wide enough nor deep enough to insure an impervious base, and it is doubtful if any muck ditch alone could have accomplished such a result. It is possible that, in time, as now constructed, the subsoil will fill up with the finer sediment to such an extent as to put an effectual stop to serious leakage such as might result in another break; but

the risk is too great, and the interests at stake are too important to rely on this expedient alone. Mr. Ockerson.

In comparing the work with that on other streams, it should be borne in mind that the soil has about the consistency of talcum powder when dry, and the stream has a slope down the intake of about 4 ft. to the mile. The problem of closure, therefore, is quite different from the conditions on the Atchafalaya or Missouri Rivers.

There can be little doubt, however, that several of the failures in the attempt to close the intake are traceable to defects in the methods used, and the failure to utilize ordinary engineering practice in such cases. Five of the failures were apparently due to neglecting the very important feature which is the key to success in work of that character, namely, that, first of all, the approaches to the work contemplated must be securely fixed. The banks and bed must be made stable beyond the possibility of erosion. Had this been done, the first effort to close the intake would have succeeded, and the cost would have been a few hundred dollars instead of the several hundred thousand which have been expended. The integrity of the "Rockwood gate" could probably have been preserved by the same means.

The two latest closures were certainly executed in as expeditious a manner as any previous work of such magnitude, and the engineers and others who participated in the work deserve great credit therefor.

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PAPERS AND DISCUSSIONS.

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MOVABLE BRIDGES.

Discussion.*

By Messrs. Ralph Modjeski, Wilbur J. Watson, W. M. Hughes and J. P. Snow.

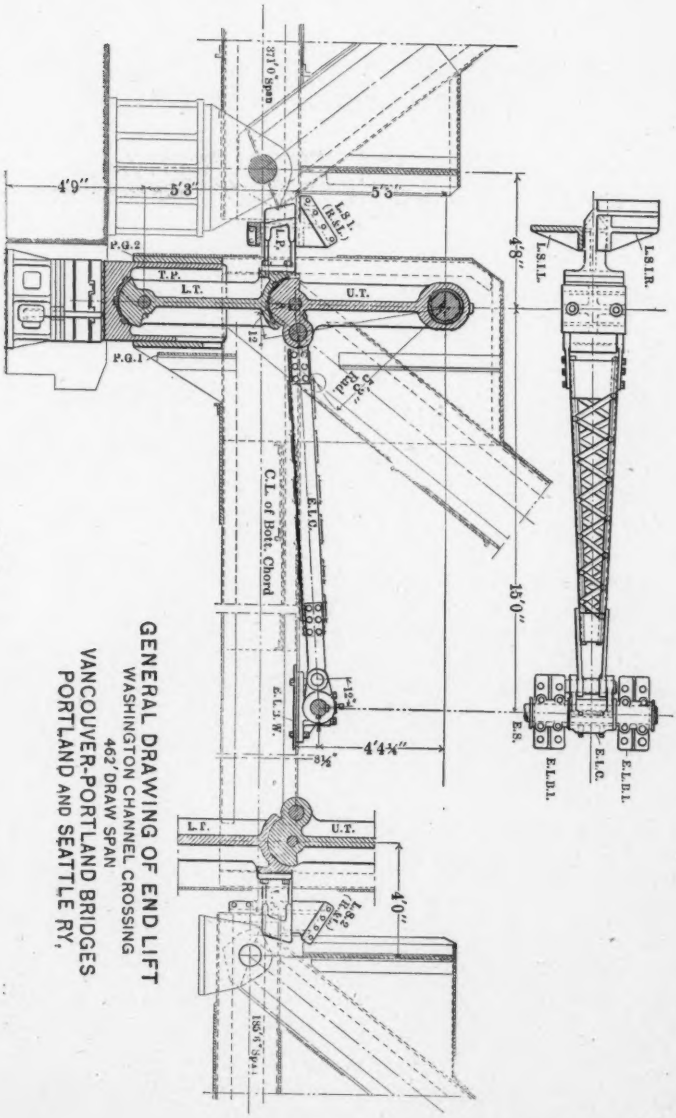
Mr. Modjeski.

Ralph Modjeski, M. Am. Soc. C. E. (by letter).—No subject of equal importance has received less attention in the way of publications and discussion in professional papers than the one treated by the author. In all the so-called standard specifications for bridge superstructures clauses relating to movable bridges seem to have been carefully avoided, and yet such bridges constitute the most expensive part of a railroad, both as to first cost per foot of track and as to maintenance and operation. The subject is quite complex, covering a great variety of structures under variable conditions. Mr. Schneider's very clear and concise paper is valuable because it embodies, probably, the first general specification on movable bridges, and because it opens the field for a thorough discussion.

With regard to end lifts, the author expresses his preference for wedges, and does not recommend "that kind of end lift which supports the ends of the bridge, when closed, on rollers, toggle joints or links." The writer has used rollers quite successfully. Plate LXI shows the roller end lifts used by him in the Rock Island Railroad and Highway Bridge which have given entire satisfaction. It will be noticed that the lower casting has inclined instead of horizontal bearing surfaces; and that each roller, when the span is fully raised, comes into contact with a convex surface

* Continued from April, 1907, *Proceedings*.

Mr. Modjeski.



GENERAL DRAWING OF END LIFT
WASHINGTON CHANNEL CROSSING
462' DRAW SPAN
VANCOUVER-PORTLAND BRIDGES
PORTLAND AND SEATTLE RY.

FIG. 1.

Mr. Modjeski.

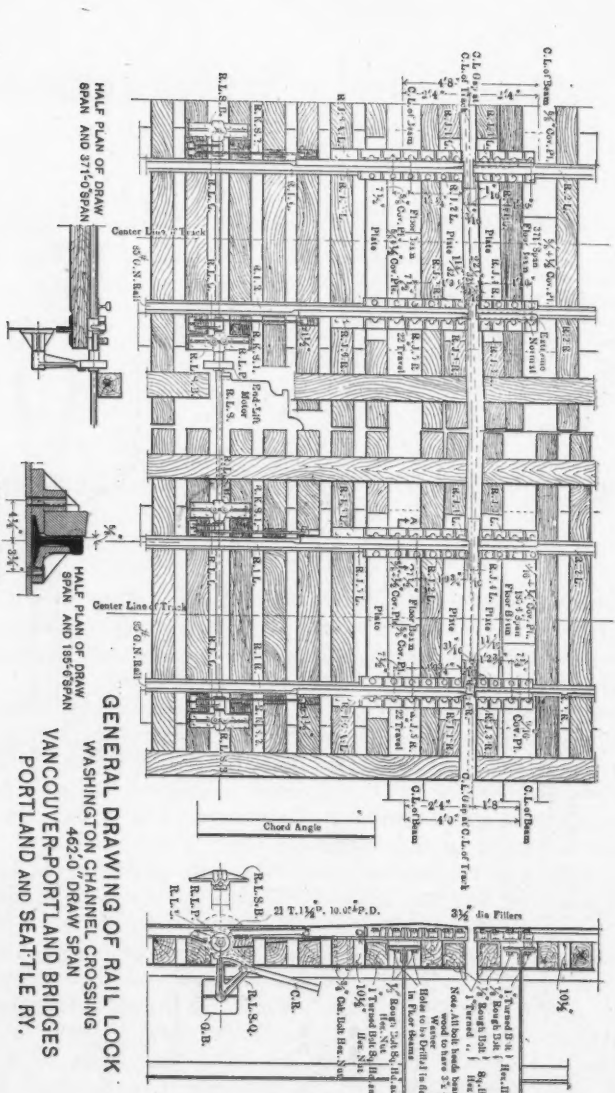
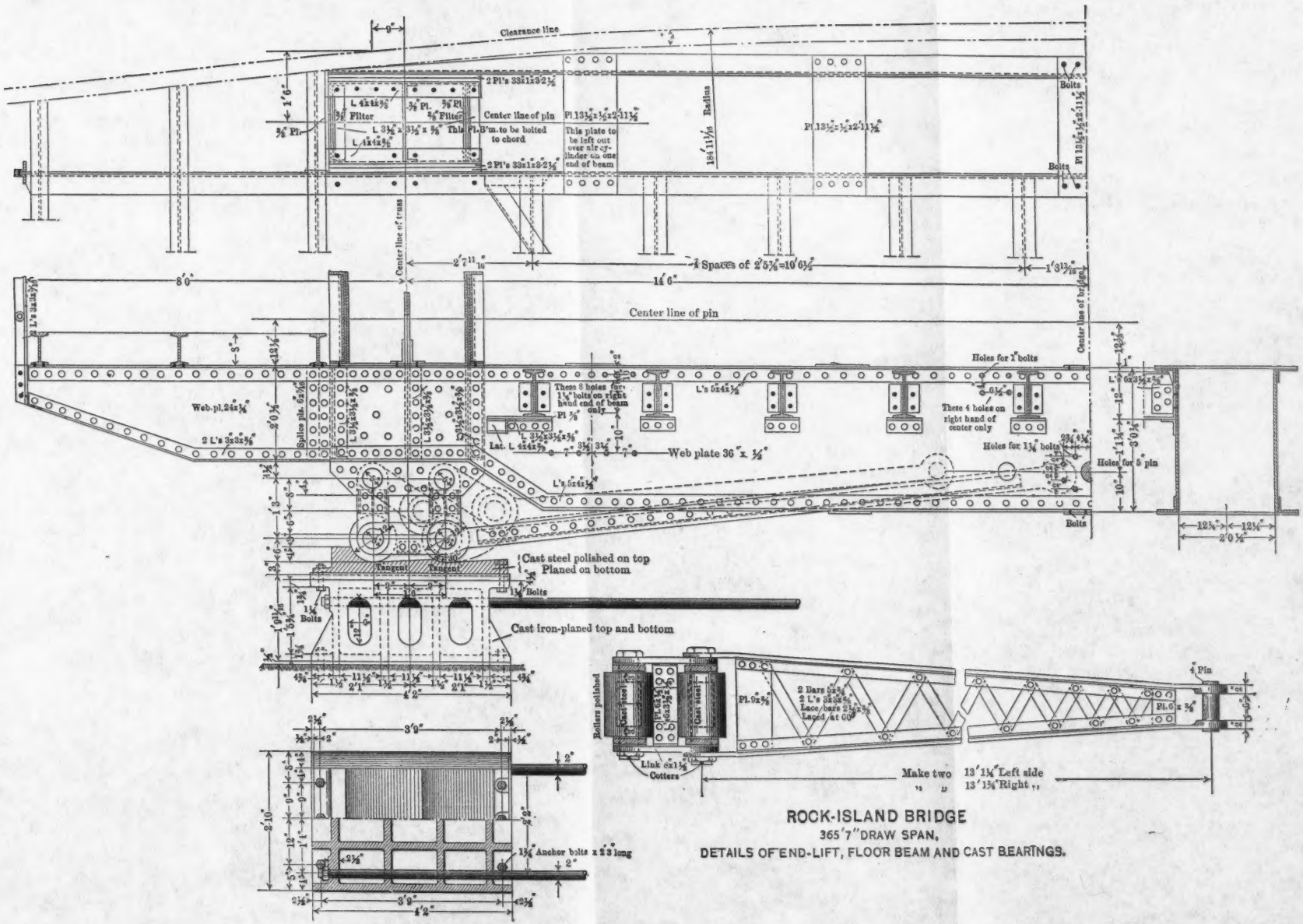


Fig. 2.



ROCK-ISLAND BRIDGE
365'7" DRAW SPAN.
DETAILS OF END-LIFT, FLOOR BEAM AND CAST BEARINGS.

which acts as a stop. By this arrangement, when the end of the span is fully raised, the contact between each roller and the bed-plate is an area, and not a line as is the case in many roller lift designs. This device has the further advantage of centering the span and locking it automatically; and there is less frictional resistance than when wedges are used. Owing to the sloping bearing surfaces of the bed-plates, the rollers tend to remain in place when set. Mr. Modjeski.

The writer presents, in Fig. 1, a design for an end lift of an entirely different character, which will be used for a 462-ft., double-track span over the Columbia River, and also for a 521-ft., double-track span over the Willamette River. The toggle has been made very powerful and substantial, and suitable for heavy loads. The bearing takes place on a nest of segmental expansion rollers which right themselves whenever the bearing blocks are raised and the pressure is removed. As this design has not yet been installed, and, therefore, has not received the sanction of a trial, the writer will abstain from discussing it herein. Both these devices dispense with the automatic latches required by Mr. Schneider's specifications. It has been the writer's experience that such latches, if effective in holding the bridge truly lined up, must have very little play when in a locked position, and, therefore, must always produce a certain shock in locking, and this the writer believes to be objectionable in heavy bridges.

The author calls for rail-lifts in his specification. The writer believes that the rail-lift will soon be entirely superseded by safer devices; one of them recently recommended for adoption by, at least, one important railway system, is essentially the same as the rail-lock used by the writer, first on the Rock Island draw, and, later, on all draw spans designed by him.

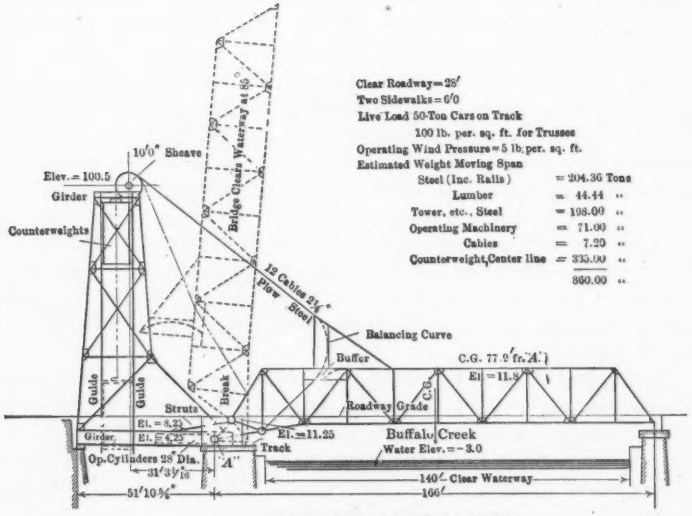
Fig. 2 shows the rail-lock which will be used on the Columbia and Willamette River draw spans. The principal advantages are: Practical continuity of the rail over the gap—the key is shaped so that it raises the wheel slightly before it reaches the end of the gap, and sets it down on the second rail some distance from its end; and the rails are permanently fastened to the ties.

A sliding-key rail-lock was used on the old Rock Island draw span before its reconstruction. In the writer's design, the old form of lock has been modified by making the key beveled lengthwise and crosswise on top, instead of level, and by providing more efficient guide-bars.

Wilbur J. Watson, M. Am. Soc. C. E. (by letter).—The writer has recently been called upon to design several bascule bridges, and will take advantage of the author's invitation to discuss this feature of the paper. Mr. Watson.

Mr. Watson.

The bridge illustrated in Fig. 3 is a single-leaf highway span, 166 ft. from center to center of bearings, now under construction at Buffalo, N. Y. In this design, the balance is maintained by a detached counterweight, moving vertically between fixed guides attached to a tower which carries two 10-ft. cast-steel sheaves, over which pass twelve 2¼-in. plow-steel cables, which pass around grooved tracks attached to the trusses, and placed so that the lever arm of the ropes about the point of rotation maintains a constant ratio to the lever arm of the center of gravity of the moving span. The counterbalancing scheme of this bridge, as well as the hydraulic



OHIO STREET BASCULE BRIDGE
BUFFALO, N.Y.

FIG. 3.

operating machinery, is the design of T. E. Brown, M. Am. Soc. C. E.

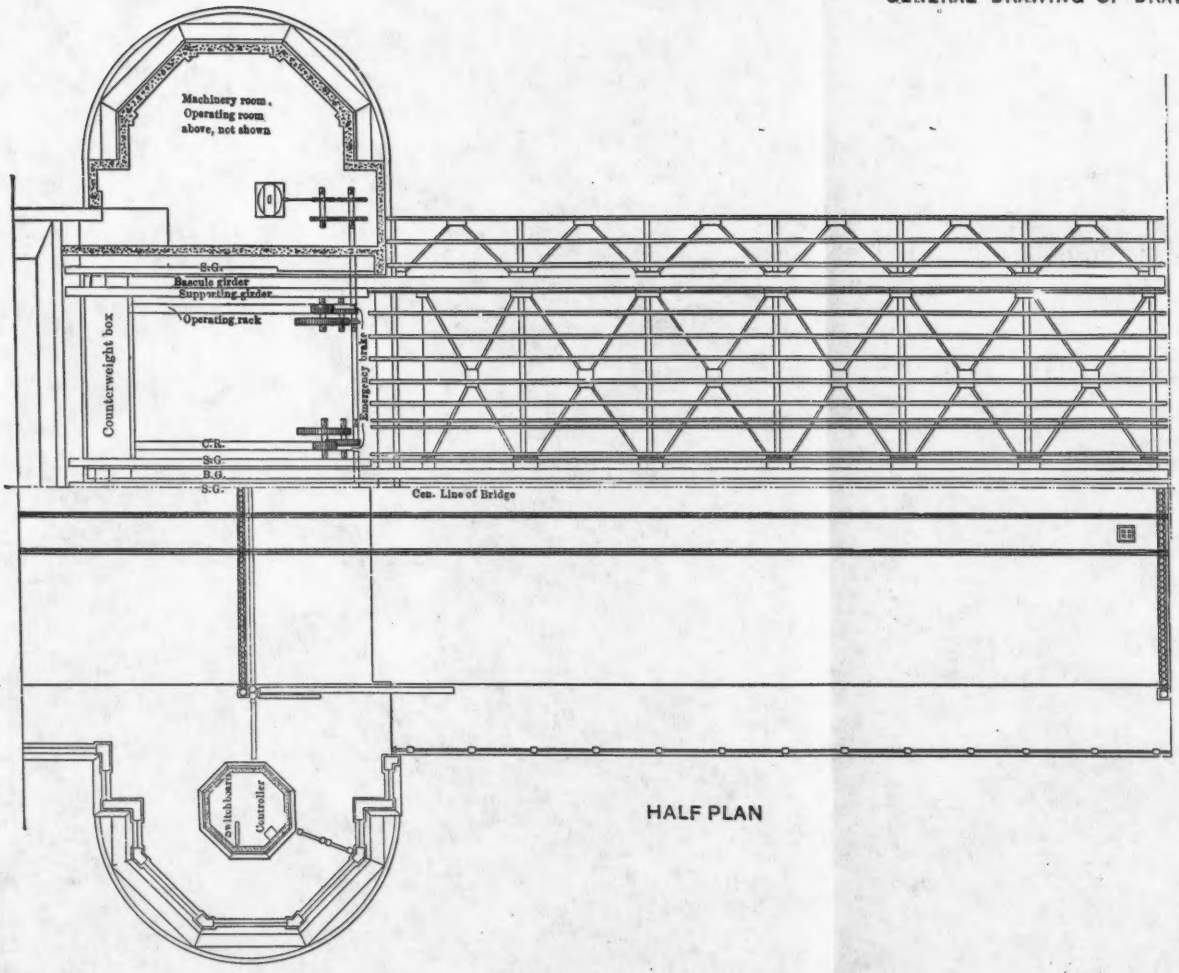
The bridge illustrated in Fig. 4 is a design proposed by the writer for a similar structure, the idea being to secure a tower which would be symmetrical and attractive in appearance, and also to produce an economical design. In this design, the cables are attached to fixed points in the trusses, and pass around sheaves of the proper diameter, being securely fastened thereto. The counterweights are carried by chains, built up of steel plates and pins. These chains pass around, and are wound upon, spiral sheaves mounted upon the same shafts as the first-mentioned sheaves.

The reason for using chains instead of cables for hanging the counterweight is that such chains can be wound around a drum of

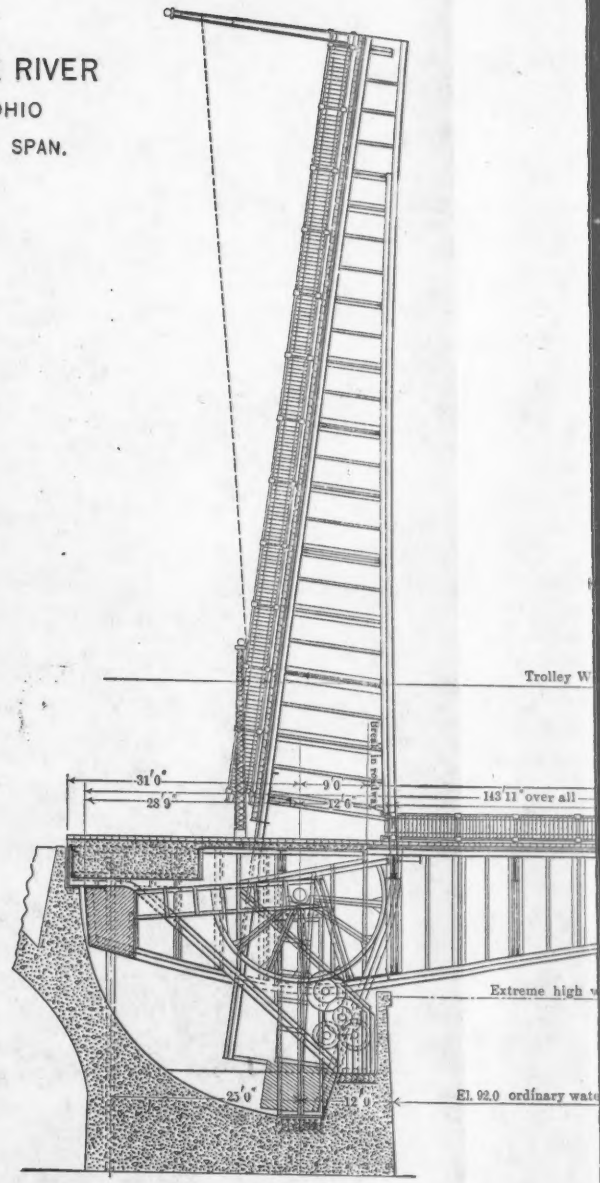
BRIDGE OVER MAUMEE RIVER

ON CHERRY ST., TOLEDO, OHIO

GENERAL DRAWING OF DRAW SPAN.



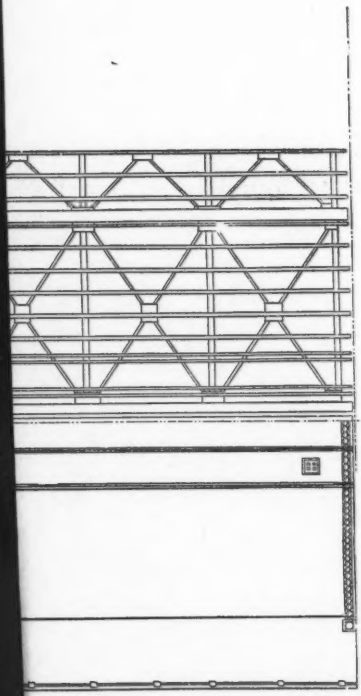
HALF PLAN

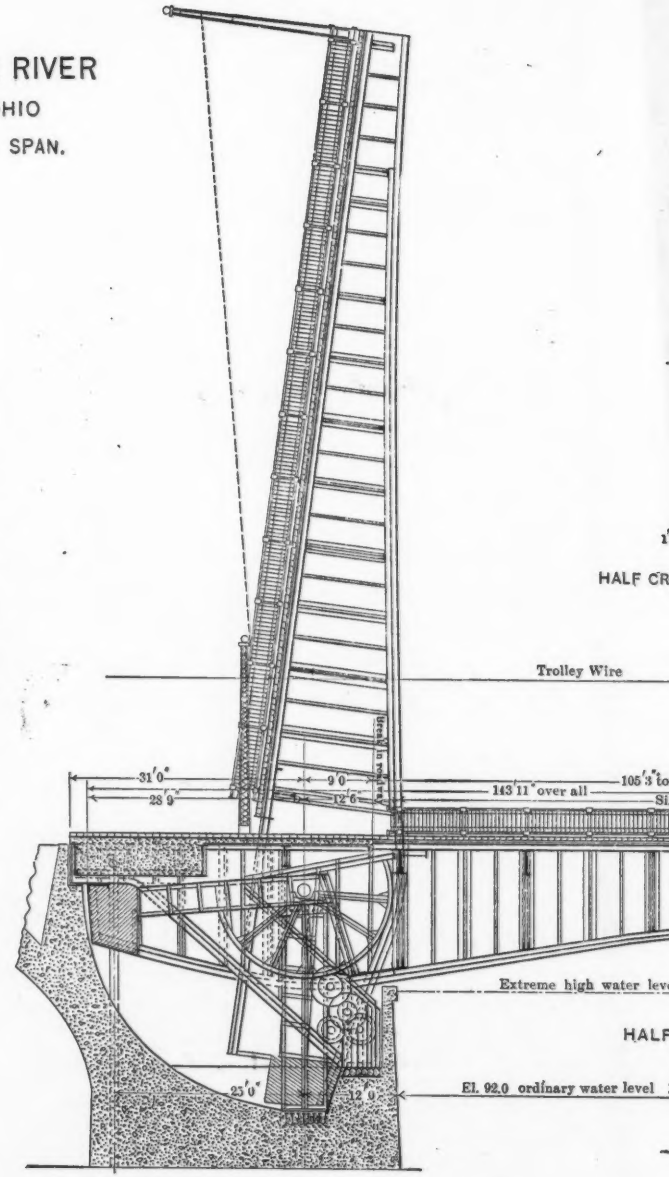


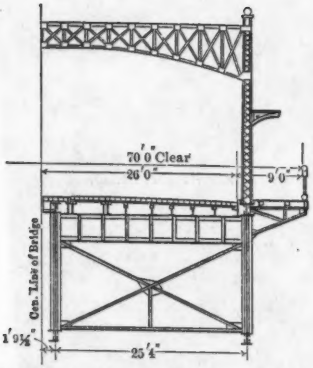
BRIDGE OVER MAUMEE RIVER

ON CHERRY ST., TOLEDO, OHIO

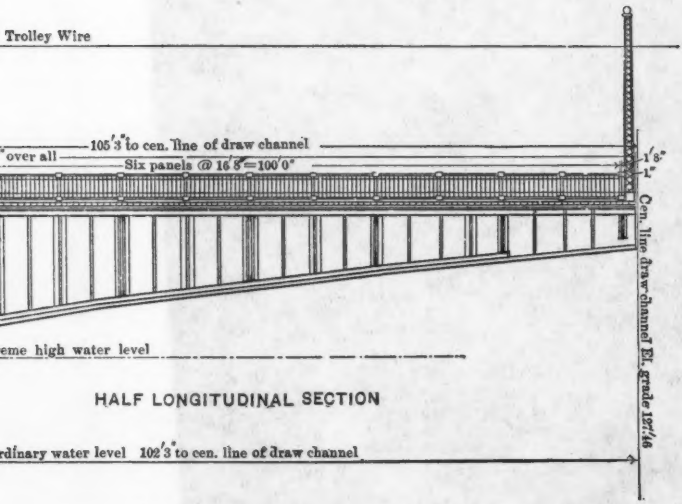
GENERAL DRAWING OF DRAW SPAN.







HALF CROSS-SECTION THROUGH BASCULE GIRDERS



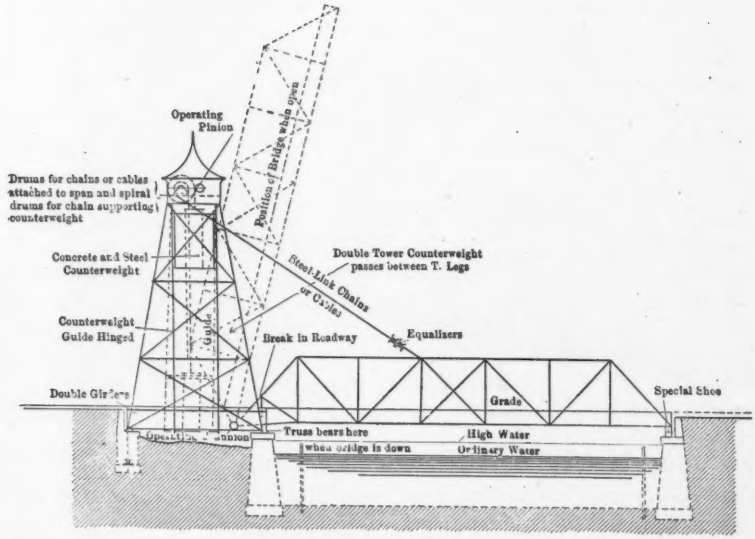
HALF LONGITUDINAL SECTION

rdinary water level 102′3″ to cen. line of draw channel



very small diameter, much smaller than would be advisable in the case of cables. Mr. Watson.

A further advantage of this design is the simplicity of the operating mechanism, for, by placing the trunnion far enough back so that the forward, or positive, moment of the span will always be in excess of the backward, or negative, moment of the wind pressure, it is possible to operate the bridge by a pinion engaging a gear attached directly to the shafts which carry the balancing sheaves, and operated by the usual electric motor and gear trains.



THE WATSON BASCULE BRIDGE

FIG. 4.

With such a design, it is practicable to use a counterweight of less than half the weight of that ordinarily used on bascule bridges having attached counterweights, with a consequent reduction in stresses in the structure and in the machinery, and less load on the foundations.

In discussing these designs with other engineers, the writer has discovered that there exists, among bridge engineers, a very strong prejudice against the use of cables and chains, and it is this prejudice to which he desires particularly to call attention, in order to discover, if possible, the reasons therefor. It has been his experience, and is his firm belief, that nothing will give more satis-

Mr. Watson. factory service than chains and cables for such uses, provided that they and their sheaves and fastenings are proportioned properly.

The writer uses a value of 800 lb. per sq. in. for the bearing of axle steel on phosphor-bronze in the case of slow-speed bearings, instead of the 2 000 lb. given by the author.

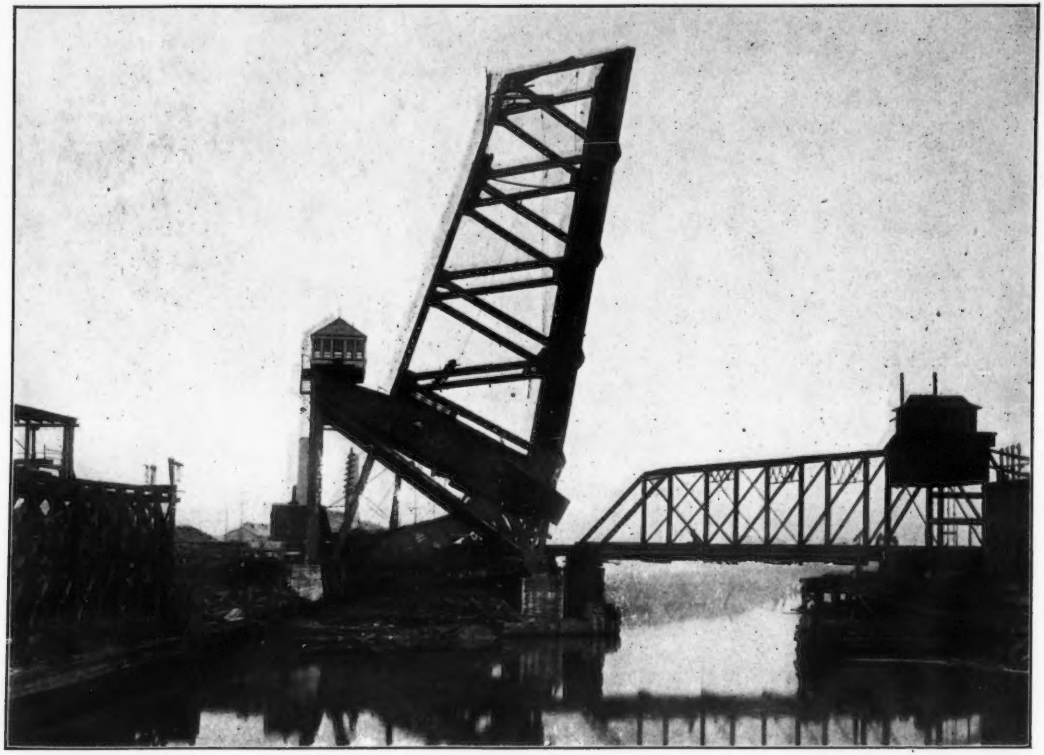
Plate LXII illustrates a simple, trunnion, deck-bascule span, designed by the writer for the City of Toledo. It is the writer's opinion that the simple trunnion type for deck bridges has been neglected by engineers, suffering, perhaps, from the fact that it is not a patented type, and, therefore, has not been strenuously advocated by patentees. There are doubtless cases, where, by reason of limited clearance conditions, it is advisable to hinge the counterweight, in order to make its path of travel conform to the said clearance conditions, but, when it is possible to attach the counterweight to the moving span securely without increasing its amount materially, it seems to the writer, that the advantage of simplicity of design far outweighs any advantages to be gained by hinging the counterweight.

In regard to controllers for operating double-leaved bascule bridges, the author's specifications call for controllers of the series-parallel type. Now, as it is usually desirable, and required, that a single operator shall be able to operate both leaves from one side of the bridge, controllers of this type require a great number of wires of large capacity to be carried in conduits under the opening. Cannot this result be attained better by using automatic controllers operated by two master switches, which would require much less wiring under the river, and, it seems to the writer, be a safer method of control?

Mr. Hughes. W. M. HUGHES, M. AM. SOC. C. E. (by letter).—The writer, in the capacity of Designing and Consulting Engineer, has recently completed, for the Chicago and Alton Railway Company, over the South Fork of the Chicago River, a double-track bridge of the Page bascule type, having a single leaf 150 ft. in length (Plates LXIII and LXIV).

With regard to the proper wind pressure to be used in the design of bascule bridges, the writer knows of no reliable information, but this should be available, considering the number of bascule bridges which have been built during the last few years. From observation during the operation of the Chicago and Alton Bridge, with a wind velocity exceeding 30 miles per hour, the ammeter indicated but little increase in the power required. The writer believes 15 lb. per sq. ft., corresponding to a velocity of from 50 to 55 miles per hour, to be ample.

In bascule bridges of the Page type the operating machinery is carried by longitudinal and transverse girders, the latter being connected to the inside counterweight girders, and the power is



PAGE BASCULE BRIDGE OVER SOUTH BRANCH OF CHICAGO RIVER, AT BRIDGEPORT, FOR THE CHICAGO AND ALTON, SANTA FÉ, AND ILLINOIS CENTRAL RAILROADS.

transmitted to the movable leaf by a pinion engaging in a rack which is bolted to the track girder, the latter being connected to the chords of the trusses of the movable leaf. The shaft, to which this pinion is keyed, also carries the rollers, which transmit the counterweight to the track girder. This shaft consists of a hollow steel casting, 24 in. in diameter, the hole being 17 in. The size of this shaft is fixed by the area for the bearing of the rollers, which have phosphor-bronze bushings, the allowed pressure being 1 200 lb. per sq. in. These rollers make less than three revolutions in opening or closing the bridge. Mr. Schneider's specification allows, for moderate speeds, only 600 lb. per sq. in., and, for trunnion bearings, 2 000 lb. per sq. in. The writer is of the opinion that the former is too low and the latter too high. In the design of the Chicago and Alton Bridge, he used 1 200 lb. for the trunnion, more particularly for the purpose of insuring proper lubrication, this being more difficult in the case of the trunnion from the fact that it makes less than one-fourth of a revolution in opening or closing the bridge. Mr. Hughes.

The rule given by Mr. Schneider for the size of keys would hardly be applicable to a 24-in. shaft, which would require two keys, each 2 by 4 in. The keys used for the 24-in. shaft in the Chicago and Alton Bridge were 2 by 2 in., and were considered ample. This, however, may be a special case, as the diameter of the shaft was fixed to give the proper bearing area for the rollers.

When electric motor power is used for the operation of bridges, the writer is of the opinion, that it is desirable to use two motors, each of sufficient capacity to handle the bridge, possibly at a somewhat reduced speed, with one motor only in service. This adds slightly to the first cost of the bridge, but practically nothing to the cost of operation, and makes far less the chances of the bridge being thrown out of service, due possibly to the armatures burning out, or some other accident to the motor. When two motors are used, each with sufficient capacity to operate the bridge, it would be hardly reasonable to design the machinery with the usual factor of safety for the full capacity of both motors; although, no doubt, some additional allowances should be made, say 50%, which would provide amply for depreciation due to wear.

J. P. Snow, M. Am. Soc. C. E. (by letter).—This paper is the most practical guide to the design of movable bridges with which the writer is acquainted. The author's conclusions are sound, but it is to be feared that the limitations placed by him upon certain types of swing bridges will be taken, by some, to mean more than was, perhaps, intended. Mr. Snow.

Jack-knife and shear-pole bridges can be readily built with clear openings of 50 ft. This will accommodate an immense amount of navigation under certain regulations. Wider openings are needed on navigable rivers, but around harbors, where draw-bridges are

Mr. Snow. oftentimes very numerous, narrow openings are, on some accounts, distinctly advantageous.

Shear-pole draws cannot be used to advantage except for narrow highways and single-track railways. Two tracks can, of course, be accommodated by two independent structures swinging in opposite ways. Jack-knife draws may be coupled up for four tracks, and, by using two structures swinging in opposite directions, eight adjacent tracks may be handled, as is done on the Boston and Maine Railroad at Boston.

The unbalanced feature in these two types of swing bridges is their worst point. While swinging, they must be held by guys or braces, or both. The lack of a stable attachment for these supports limits the available span of such structures. Proper connection between these attachments and the heel of the trusses is the key to the successful operation of these bridges. Their advantages are: small first cost, quick operation, and less space required outside the tracks than for other kinds of swing bridges.

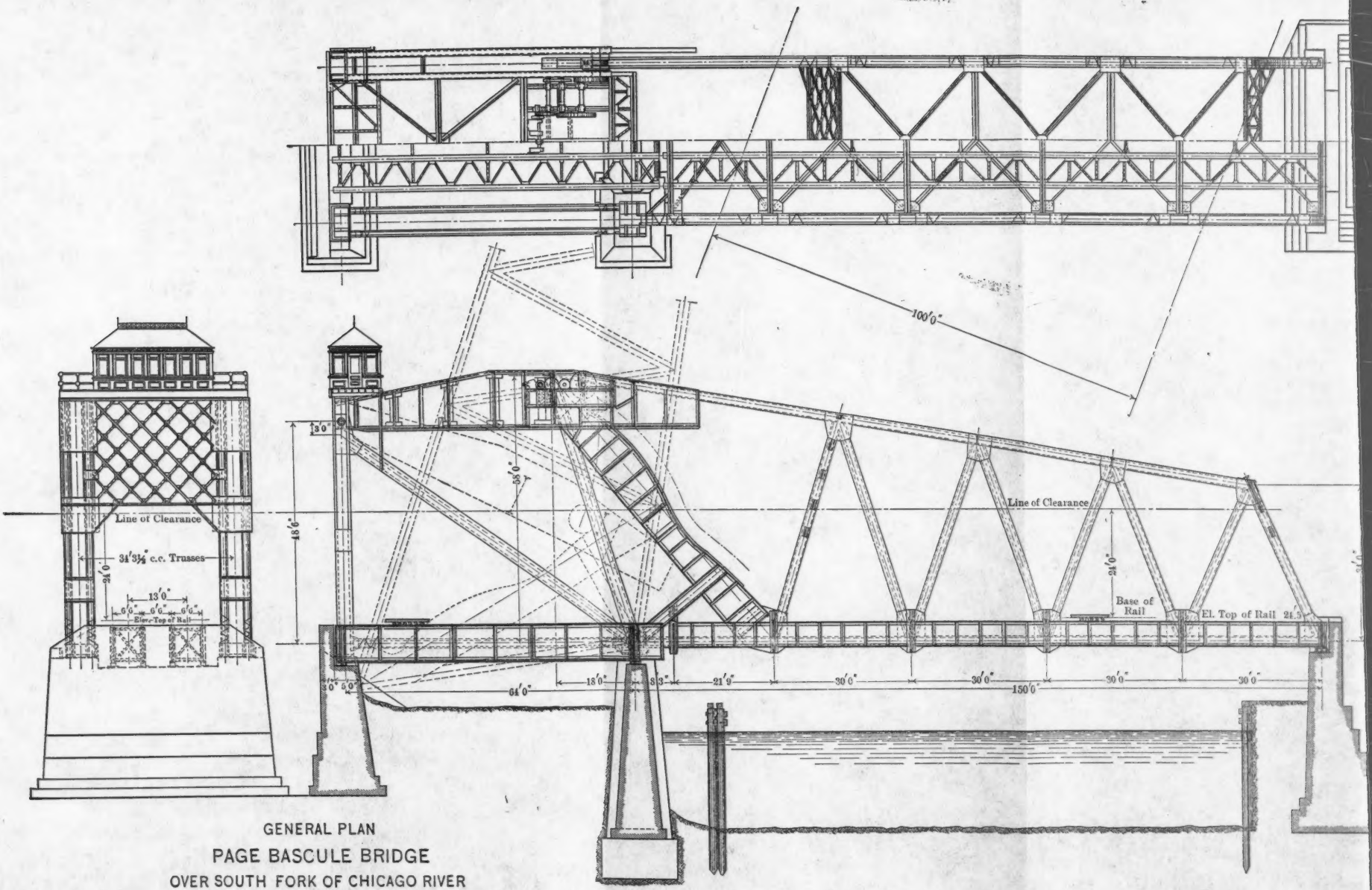
The rim-bearing swing bridge deserves an advocate who will class it a little higher than the author, and, no doubt, in the discussion, an advocate will appear who can handle the subject much better than the writer.

It is true that less power is required to turn a center-bearing bridge than one bearing on a rim; and, if the bridge is to be turned by hand, the former type should be selected. If mechanical power is used, the difference in the amount required is of little importance. Rim-bearing bridges will give trouble if the pier is not firm and intact; and either kind will give trouble if it is not properly built.

A circular drum is no doubt an excellent and very natural feature to carry the upper track of a rim-bearing bridge, but it is not essential. It is not unusual to attach the upper track to the carrying girders and to corner girders attached to them. In this case it is well to make the top track a horizontal plane and set the roller axes inclined. If the diameter of the rollers is made small, excellent results are obtained.

It is essential that the pier for a rim-bearing bridge should be of masonry which will remain in place and hold rigidly the parts attached to it. With this condition fulfilled, very good results have been and can be obtained without connecting the center and lower tracks, as recommended by the author. Such connection, although excellent in itself, will be somewhat difficult and objectionable with stone masonry. With concrete, on the contrary, the bracing can be built into the masonry, and the objection pertaining to stonework will be avoided.

There are in service many rim-bearing bridges which are giving excellent results, and they can be built to do this, if the details are good, without unusual refinements of workmanship.

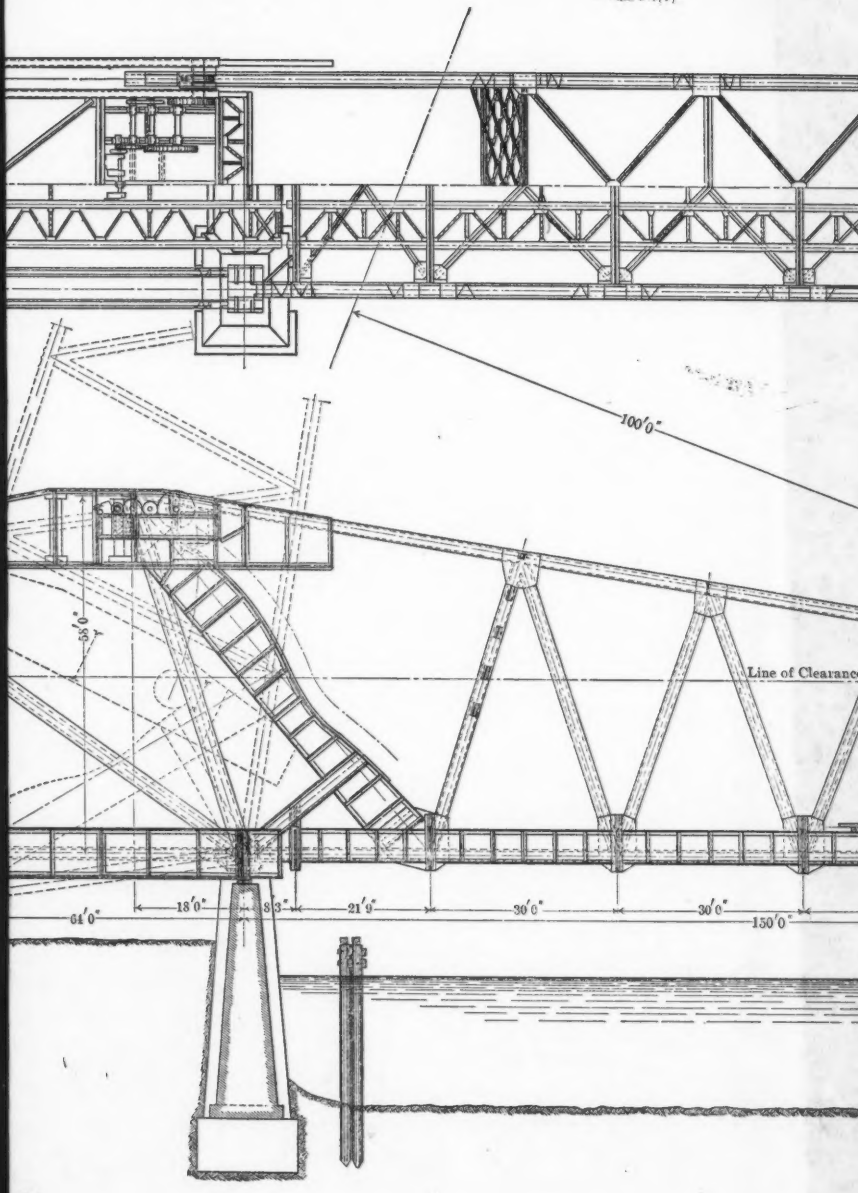


GENERAL PLAN

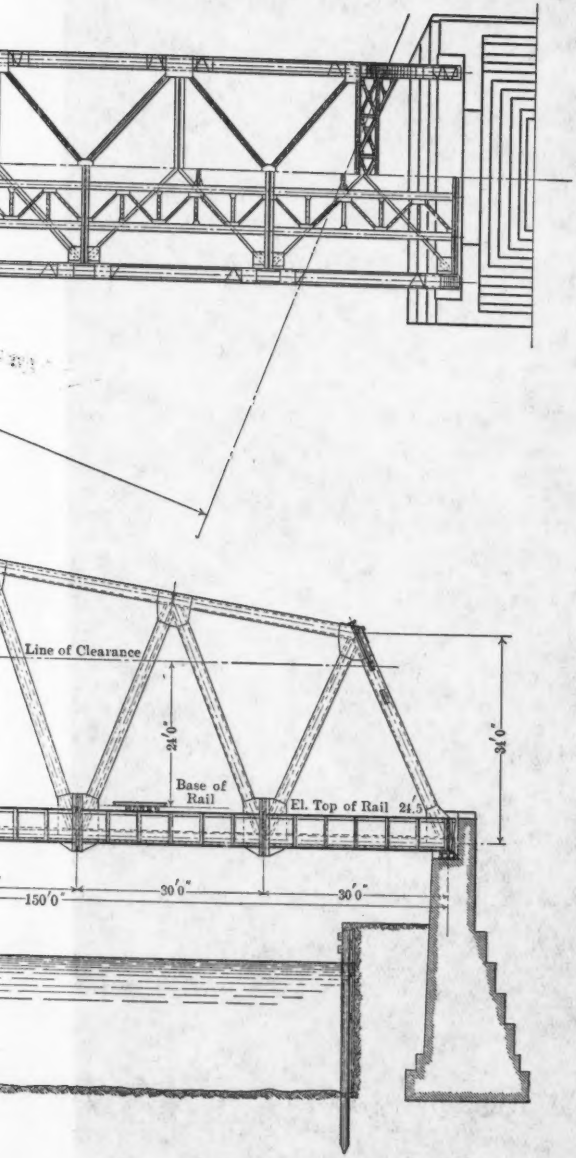
PAGE BASCULE BRIDGE

OVER SOUTH FORK OF CHICAGO RIVER

C. & A. RY.—C. M. & N. RY. AND A. T. & S. F. RY.



RY.


Line of Clearance
21'0"
Base of Rail
El. Top of Rail 21.5
31'0"
150'0"
30'0"
30'0"

Vol. XXXIII. MAY, 1907. No. 5.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

THE EFFECTS OF THE SAN FRANCISCO EARTHQUAKE OF APRIL 18TH, 1906, ON ENGINEERING CONSTRUCTIONS.

REPORTS OF A GENERAL COMMITTEE AND OF SIX SPECIAL COMMITTEES OF THE SAN FRANCISCO ASSOCIATION OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Discussion.*

BY MESSRS. EDWIN DURYEA, JR., FRANKLIN RIFFLE, H. H. WADSWORTH, EMILE G. PERROT AND LUTHER WAGONER.

Mr. Duryea.

EDWIN DURYEA, JR., M. AM. SOC. C. E. (by letter).—The writer wishes to call attention to one of the conclusions of the Committee on Fire and Earthquake Damage to Buildings which he believes to be too severe to be warranted by the facts. He recognizes that the members of this Committee had more opportunities to judge of the effects of the earthquake on buildings than he had, but, notwithstanding this, he has incidentally seen a sufficient number of instances of ordinary brick buildings which were not seriously damaged by the earthquake to make the very severe conclusions of the Committee as to such buildings seem to be unjustifiable.

*This discussion (of the Reports on the San Francisco Earthquake, printed in *Proceedings* for March, 1907), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Duryea.

The particular statements to which exception is taken are the following:*

"The building with stone, brick or block construction, having horizontal mortar joints, does not answer the requirement (elasticity) at all. It may be stated, as one of the most obvious lessons of the earthquake, that brick walls, or walls of brick faced with stone, when without an interior frame of steel, are hopelessly inadequate. As a method of building in earthquake countries, such types are completely discredited."

And again:†

"The writers simply reiterate the statement that, speaking generally, buildings of brick walls and wooden interiors cannot be built which will not be wrecked in a severe shock, it being a fault of design and not of materials or workmanship."

This conclusion is so severe that, if it were true, it would entirely exclude the safe use of ordinary brick buildings, for any purpose, on the San Francisco peninsula. It would seem that even the few instances of brick buildings which have withstood the earthquake with little or no damage would make such a conclusion unjustifiable. The writer has taken no pains to find such examples, but believes that he has seen a number of brick buildings which, while including no steel in their framework, have passed through the earthquake with very little damage. As specific instances, he would mention the brick church on the south side of Geary Street between Gough and Octavia Streets, the stone church on the southwest corner of Geary and Franklin Streets, and the brick cathedral on the northwest corner of Van Ness Avenue and O'Farrell Street. The cathedral does not appear to have been injured at all, the stone church only by the fall of its spire, and the brick church by only slight damage to its spire. The writer has no exact knowledge as to the framework construction of these churches, but, from their appearance, it is very improbable that any steel framework was used. It would seem that church buildings, with their open interiors and large roof spans, would be especially subject to injury from earthquakes.

On the morning after the earthquake, and before the fire had reached them, the writer twice passed by a number of brick warehouses on the north side of the Southern Pacific Railroad, between Fourth and Sixth Streets, and took a little time to examine them. They were of the commonest class of brick warehouse structures, neither design nor construction showing any special care, yet they had sustained relatively little damage; they also had the disadvantage of being built on extremely poor foundations, their settlement during the earthquake, with respect to the railroad right of

* *Proceedings*, Am. Soc. C. E., March, 1907, p. 325.

† *Proceedings*, Am. Soc. C. E., March, 1907, p. 327.

way, just south of them, being about 2 ft. These warehouses were afterward entirely ruined by the fire. Mr. Duryea.

It seems that, judged even by statements in the body of the report, the conclusion quoted is hardly warranted. In regard to damage to ordinary brick buildings, the Committee says:*

"It must be recognized that buildings of this type were general throughout the region of the shock. The damage ranged from slight cracks to complete destruction of large structures, hence no general statement covers the case. A few individual statements may be of interest. In Oakland, a concrete-block building, 4 stories high, was injured little if any. At Palo Alto, two such structures, 2 stories high, probably not very well built, were completely wrecked, the blocks being broken and disintegrated."

After such a statement as this—that some brick buildings were but little damaged by the earthquake—and in view of the instances known specifically to the writer where ordinary brick buildings suffered but little damage, it seems that the very severe conclusion of the Committee is unwarranted; and that, recognizing the influence of good or bad foundations and of good or bad design, or material, some conclusion less unfavorable to this type of building would have been more just and more nearly in agreement with the facts. It is undeniable, of course, that such buildings are far from being as resistant against earthquake shocks as buildings of Type 3; the latter, however, are frequently entirely beyond reach because of their great cost; and the writer believes that the ordinary brick building, though generally inadvisable where financial consideration will permit of a better one, has shown, by numerous instances, that it may often pass through an earthquake practically unharmed, and, therefore, should not have such unqualified condemnation as that given by the Committee on Buildings.

FRANKLIN RIFFLE, M. AM. SOC. C. E. (by letter).—The writer fully agrees with the Committee on Fire and Earthquake Damage to Buildings that both wood and steel frame structures are admirably adapted to withstand earthquake shocks, but he is not prepared to endorse the unqualified condemnation of a type of construction which, after making due allowance for numerous instances of inadequate foundations and poor workmanship, has proven itself capable of much greater resistance to shocks than the Committee apparently is willing to concede. Mr. Riffle.

The process of reasoning whereby the Committee arrived at its conclusions regarding brick buildings appears to be about as follows: An earthquake sets up, in a structure, a swaying motion, the tendency of which is to distort the frame; if sufficiently elastic, as is the case with wood, steel, and reinforced concrete construc-

* *Proceedings*, Am. Soc. C. E., March, 1907, p. 321.

Mr. Riffle. tion, the structure returns to its original form after distortion; if not elastic, as in the case of stone, brick, or block construction having horizontal mortar joints, the structure is ruptured or wrecked. The latter type is then summarily dismissed with the phrases "completely discredited" and "hopelessly inadequate." It is true that the Committee cited a few examples of the failure of brick buildings, to give practical support to its theoretical deduction; but, leaving theory entirely out of the question, the citation of a few examples, coupled with the information that "the damage ranged from minor cracks in brickwork to the complete destruction of large buildings," does not seem to justify the following sweeping conclusions:

"* * * as one of the most obvious lessons of the earthquake, that bricks walls, or walls of brick faced with stone, when without an interior frame of steel, are hopelessly inadequate. As a method of building in earthquake countries, such types are completely discredited."

"* * * speaking generally, buildings of brick walls and wooden interiors cannot be built which will not be wrecked in a severe shock, it being a fault of design and not of materials or workmanship."

It is the opinion of the writer that the one great lesson taught by the earthquake is not the inadequacy of any one of the well-known types of building construction, but the necessity of adhering more rigidly, in all types, to the fundamental principles of good design, good materials and good workmanship. It is safe to say that a careful investigation of all the building failures which resulted from the earthquake, would, in most cases, bring to light serious infractions of the commonly accepted rules for safe construction, which would account for much that the Committee would attribute to inadequate design or type.

During the first day of the fire the writer spent several hours in the district in which brick buildings were the prevailing type, and made note of the fact that most of these were in good condition before the flames gutted their wooden interiors and reduced their walls to ruins.

If the Committee had included in its investigations the brick buildings in the Potrero and Mission Districts of San Francisco, which escaped the fire, it is doubtful if it would have condemned this type of construction in its otherwise excellent report. Almost without an exception, these buildings either were not damaged at all, or were damaged so slightly that the cost of repairs was trivial; and this applies to some buildings which had not been constructed in the substantial manner which engineers and architects would consider essential, even under usual conditions.

Mr. Riffle.

A brief description of a brick warehouse in the Potrero District, which came through the earthquake almost without a crack to bear witness to the severity of the shock, will show conclusively that it is not impossible or even difficult to construct a brick building with a wooden interior "which will not be wrecked in a severe shock."

The building is on the east side of Kansas Street, between 15th and 16th Streets, has a frontage of 100 ft., a depth of 200 ft., and is 4 stories high. The site is a portion of a tract of marshy tide land, which was formerly used as a dumping ground for the city's garbage. To secure a satisfactory foundation for the walls and columns, piles were driven and cut off below the water level, or about 10 ft. below the level of the street. The foundation walls were built of concrete reinforced by twisted steel bars, while, above the street level, the walls were constructed of common brick with cement mortar joints. The side walls contain no openings, but both the front and rear walls are generously provided with large windows on each of the four floors, in addition to six wide-arched doorways on the ground floor—three at each end.

The floor systems consist of wooden beams and joists supported by heavy wooden columns. A brick partition wall divides the building into two equal parts, each 100 ft. square. At the intersection of the partition wall with the north side wall, a portion of each of the two intersecting walls was carried to a height of about 20 ft. above the roof. These walls formed a support for a water tank about 15 ft. high and 12 ft. in diameter, which was full of water at the time of the earthquake. Both the building and the tank withstood the shock (or series of shocks) without sustaining any damage whatever. There was nothing unusual about the methods used by the architect. The work was done by contract under the personal supervision of an inspector acting under the architect's instructions. The results obtained naturally followed the careful observance of the commonly accepted standards of good building practice. During the past year the owner of this building has constructed two similar buildings in the same block. In the light of their experience, who will say that the owner and architect were not fully justified in adhering to a type of construction which the Committee has so mercilessly condemned as being "hopelessly inadequate"?

On Rhode Island Street, less than one block from the building already described, is a 2-story brick warehouse which was built, many years ago, on a foundation of solid rock. Although, for a period of several years, it has presented a somewhat dilapidated appearance from the fact that much of the mortar had disappeared from the joints, the walls were practically undisturbed by the earthquake.

Mr. Riffle. On the opposite side of the street is a 5-story brick building occupied by the National Ice Company. Owing to the unusual height of the stories, the building is about as high as a 9 or 10-story modern office building, but it was so well constructed throughout that it suffered no damage whatever.

Two blocks farther north, on Eighth Street, is another 5-story brick building which was built many years ago, and, for a long time, was used as a sugar refinery; of late years, it has been used as a syrup factory. The floors and their supporting columns are of wood construction. At the time of the earthquake the top floor was heavily loaded with tanks of syrup. The building suffered practically no damage. This is certainly a remarkable showing, taking into consideration the character of the foundation, which is reliably reported to have sunk several feet during the erection of the superstructure. The walls were well tied together by iron rods, which largely compensated for the instability of the foundation.

Going west from the Potrero through the Mission District, one may see the following brick structures, the walls of which were uninjured: The Lick School building, and the Forderer cornice works, on 16th Street; the Bryant Street Power House, of the United Railroads, and its two tall chimneys; the Union Brewery and Malting Company's tall building, on 19th Street; the Mission High School building on 18th Street; the Spring Valley Water Company's pumping station and its chimney on 17th Street; the tall brick chimney of the brick plant on West 16th Street; other structures of more or less importance could be included in this list. It is true that the number of brick buildings in this district forms an exceedingly small proportion of the total number of buildings—which are chiefly frame—but surely evidence of this character is entitled to the same consideration as that mentioned by the Committee in discussing the behavior of the limited number of steel frame buildings in the city, which were constructed with far greater care than the brick buildings just mentioned.

A brick building on Beale Street near Market, owned and occupied by a wholesale hardware company (Dunham, Carrigan and Hayden Company), was constructed upon what the architects termed a "floating" foundation, which consisted of an independent grillage of heavy timbers for each of the four walls. The floors were supported by cast-iron columns. With the exception of a few bricks which were dislodged by the shifting of the heavy cornice stones, the foundation and walls were uninjured by the earthquake, although the latter were reduced to ruins by the fire. The foundation is still intact, and will be used for another building.

The writer has not overlooked the fact that not a few brick

buildings were partially—and some wholly—wrecked by the earthquake, but it is generally conceded that most of these were so flimsily constructed that their failure was plainly due to poor materials, poor workmanship, or a combination of the two. Mr. Riffle.

The City Hall is a case in point. To many, its wreckage was no surprise, since it had long been regarded as a notorious example of vicious construction. The massive columns, which were a prominent feature of the building, consisted of cast-iron shells presumably filled with good concrete. The earthquake, however, developed the fact that loose sand, brickbats, and building refuse generally, had been largely substituted for concrete. The walls were constructed with an equal disregard for honesty and good practice.

In several other instances of partially wrecked brick buildings known to the writer, the cause of failure was clearly due to inadequate foundations. Two of these had been constructed on "made" ground, while another had been built partly in excavation and partly on embankment; in fact, poor foundations were responsible for many failures of buildings of this class. Had all the brick buildings of San Francisco been erected on as substantial foundations as those prepared for the steel frame buildings mentioned by the Committee, and had they been given equally rigid inspection during their construction, it is not too much to say that the percentage of failures would have been very small indeed. On the other hand, had the steel frame buildings been erected on inadequate foundations, there would have been a large percentage of failures recorded against this type of construction.

The writer is decidedly of the opinion that a careful, unbiased inquiry into all the facts pertaining to the behavior of brick buildings at the time of the earthquake, together with the facts regarding their construction, would not only show that, to a great extent, the conclusions contained in the reports were based on insufficient evidence and erroneous deductions, but would lead to a modification, if not a complete reversal, of the Committee's findings.

H. H. WADSWORTH, M. AM. SOC. C. E. (by letter).—Lest the report of the Committee on the Effect of the Earthquake on Highway Structures should convey the impression that such structures were singularly immune from damage by the earthquake which caused such destruction to other engineering structures in the vicinity of the region of greatest movement, the writer presents a photograph (Plate LXV) of a highway bridge across a creek tributary to Tomales Bay, near Point Reyes Station on the North Shore Railway, in Marin County, and within less than 2 miles of the fault line. This bridge was seen by the writer about three months after the earthquake, and had then been made passable for teams. Mr. Wadsworth.

Mr. Wadsworth.

The bridge, originally had eight panels, its total length being approximately 120 ft. It is located in a direction nearly north and south. The abutments are of piles and timber. The effect of the earthquake was to settle the north abutment some 2 or 3 ft., and move it southward so much that, in patching up the structure temporarily, the north end panel was not utilized as a part of the span, but the second batter post of each truss was given a footing on the abutment in its new position, thus becoming the end posts of the trusses. An apron was then built from the approach to the bridge roadway.

The stresses in the structure were thus considerably altered from those originally existing, but the bridge was still doing duty, and apparently no restrictions as to its use had been imposed by the county authorities.

Mr. Perrot.

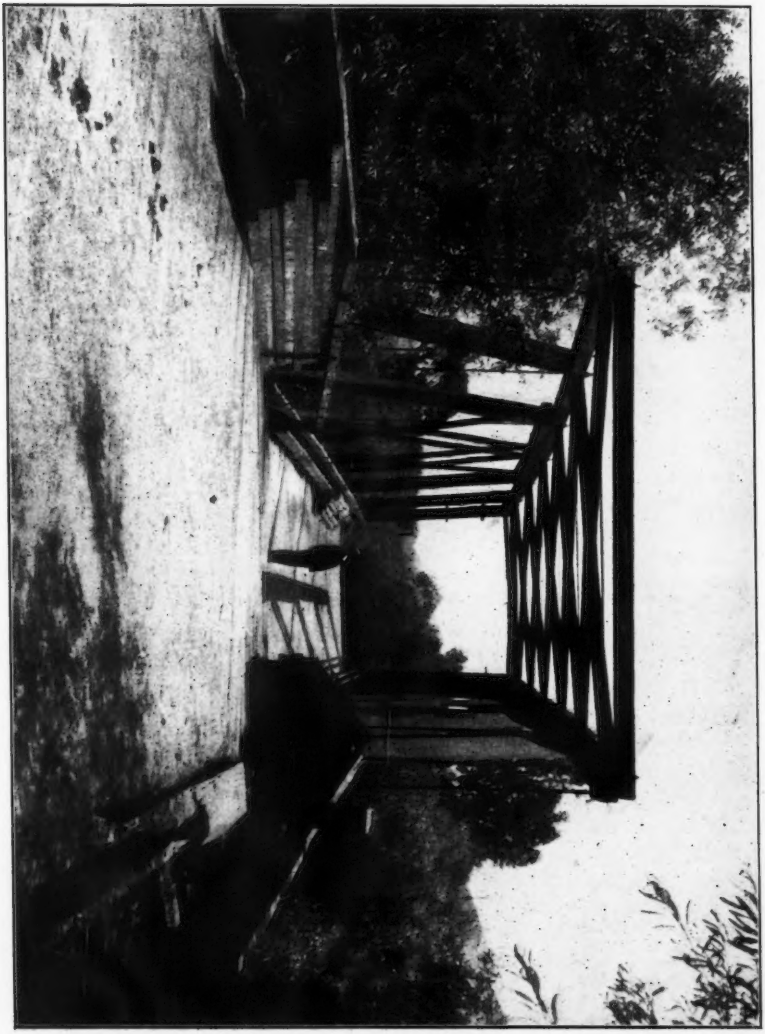
EMILE G. PERROT, ASSOC. M. AM. SOC. C. E. (by letter).—The report of the Committee on Fire and Earthquake Damage to Buildings, while very comprehensive, is lacking in some details as to the exact nature of the materials used in construction, a knowledge of which would throw more light on the subject. Some of these details, which the writer feels would be of much benefit to those interested, are the following:

Under the head of masonry walls: What was the character of the brick; how were the walls bonded; what was the composition of the mortar (lime or cement); and what was the thickness of the walls, compared with the standards of the New York or Philadelphia Building Bureaus?

Under the head of reinforced concrete: What proportions were used in the concrete; what kind of stone was used in the aggregate; and how many inches of concrete protected the rods on the bottom and sides of beams, girders, and slabs?

All these facts are of vital importance when comparing results. In most cases it is not possible to determine these details from an inspection of the work, but it might be possible to obtain records, such as specifications of the work (if they have not been burnt), which would give this information.

The Committee states that the quality of the workmanship had an important bearing on the results; that at Stanford University, where brick walls were veneered with stone, "there was a separation of the ashlar facing from the brick backing," while the buildings with full stone walls were but slightly injured. This would seem to indicate a much lower standard of workmanship in the former than in the latter case, for it is certainly not a difficult matter to bond an ashlar face to a brick backing. Further, it would lead one to believe that the standard of workmanship on the Pacific Coast was not as high as in the East, especially as the



HIGHWAY BRIDGE NEAR POINT REYES, MARIN COUNTY, CAL.

buildings at Stanford University were supposed to be of the best; what then could be expected of those buildings for which the cost had to be more carefully considered? Mr. Perrot.

The question is sometimes asked: What would happen to New York, if an earthquake occurred there? The writer does not think that a calamity, such as befell San Francisco, could befall any of the large Eastern cities, as the buildings are much better constructed in every respect.

Under the head of fire-proofing, the Committee considers solid concrete—it does not say in what proportions—at least 4 in. thick, with a mesh of reinforcement, equal to red brick set in Portland-cement mortar. It also states "that all structural parts of a building, of whatever material constructed, must be protected by another material which will be a more or less complete loss in fire," and refers to reinforced concrete as coming under this head. The writer cannot see the force of this argument. Since it is agreed that reinforced concrete is a good fire-proofing material, why not make the integral structural part larger in the first place, and do away with the veneer or covering, as it adds nothing to the strength of the member, while an additional thickness of concrete, being homogeneous with the structural part, gives it increased strength; so that, prior to any fire, the building has a greater factor of safety, and, in the event of a fire, the portions of the exterior surfaces of the concrete rendered worthless can be removed, and the parts resurfaced? The writer has seen this done with concrete damaged by frost to a depth of from 2 to 4 in.

To illustrate the point: If it were calculated that a 10 by 10-in. reinforced concrete column would be required to support a certain floor load, and if 3 in. of concrete were added all around for fire-proofing, making a 16 by 16-in. column, this column would not occupy any more floor space than a 10 by 10-in. reinforced concrete column, fire-proofed with 3 in. of metal lath and plaster or terra cotta, while there would be two and one-half times more concrete, and, consequently, two and one-half times more strength in the former column than in the core of the latter, as the plaster or terra-cotta veneer would add very little to the strength.

With regard to reinforced concrete buildings offering the solution to the problem of resisting earthquake shocks, the Committee seems to think that, as now designed, they are weak; this may be so, but it must not be forgotten that, in the East, very many large and important buildings have been built, and are being built, in which much thought has been given to just such points as those to which the Committee would call attention.

Luther Wagoner, M. Am. Soc. C. E. (by letter).—The breaks in tall chimneys, as far as observed by the writer, were in the Mr. Wagoner.

Mr. Wagoner.

middle third; the smaller chimneys, upon residences, were usually broken at the roof line, many being twisted and broken through a number of courses. One chimney, upon a brick wall, 18 by 32 in., and 7 ft. above the wall, was broken through eight horizontal courses, its top being rotated about 30° from its original position. From a careful inspection, both before and after the fire, the writer believes that most of the failures were due to lack of bond, and that the addition of a very moderate compression by the use of one or more pairs of rods, reaching preferably from base to top, and provided with turn-buckles to maintain tension upon the rods, would reduce chimney accidents to a very low percentage. The same remarks apply to walls, gables and cornices.

The writer concurs with the conclusion reached by the Committee on Fire and Earthquake Damage to Buildings that, "the prime requisite of the structure is elasticity," and, for this reason, advocates the use of moderate compression by long rods, where possible, as a proper precaution in earthquake countries. Such rods could be adjusted to maintain an elastic compression upon the top courses, and would aid in checking, and possibly wholly prevent, rotation as well as overturning.

Concerning the Committee's conclusions as to fire damages, the writer draws different ones from the same premises. He watched the burning of many of the buildings supposed to be fire-proof, and believes it is safe to say that little damage was done to the external trim by fires from adjoining buildings, but that the greater portion of such damage was due to flames issuing from the window and door openings of such fire-proof buildings. That this is a proper conclusion is evident from the fact that the greatest damage was at such openings, and that practically no damage occurred between the openings.

The only logical inference that can be drawn from the carefully compiled data of the Committee, as far as concerns the spread of a fire or the arrest of its progress during a general conflagration, is that a solid fire-wall is required to check the flame.

All these high-class buildings had large window areas—common glass in wooden sashes and frames—wooden floors and doors, and much wooden furniture, and had no more resistance to exterior fire than ordinary brick or wooden buildings.

The chief lesson to be learned from this is that such openings should have better protection.

The report of the Special Committee of the National Fire Protection Association, on the Baltimore fire, 1904, page 123, states:

"The general absence of protection at exposed wall openings is responsible for the spread of this conflagration more than any other cause. In fact, this condition may be safely stated to have been the cause for the spread of this fire beyond Fire Department control."

Mr. Wagoner.

Again, page 124:

"The contents of a fire-resistive building, without proper subdivision and no adequate protection against exposing fires, are scarcely any safer as regards destruction by fire than if contained in a building of ordinary construction."

So true and generally applicable are the foregoing quotations that they deserve to be framed and hung in the office of owner, designer and architect. Indeed all the conclusions of the above-named Committee on the Baltimore fire, pages 118 to 124, could also be deduced from the San Francisco fire.

It was stated at a meeting of the Structural Association of San Francisco, that any building had about 60% of chance of fire from an exterior attack. This was said to be due to the fact that it usually had the four sides and top as exposures, as against an interior attack; but, in a general conflagration, the attack is entirely an exterior one, hence the greater necessity of proper guards for all exterior openings and roofs.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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THE LAWS OF PROPORTIONING CONCRETE.

Discussion.*

BY MESSRS. JAMES L. DAVIS, H. DE B. PARSONS, ALLEN HAZEN, SAMUEL TOBIAS WAGNER AND R. FERET.

Mr. Davis.

JAMES L. DAVIS, ASSOC. M. AM. SOC. C. E.—As the methods given in this paper are presumably new to many, it may be of some interest to show their application to aggregates other than the two used in the experiments on which the authors' conclusions were based.

The Board of Water Supply of the City of New York, in its work of bringing an additional supply of water from the Catskills, has established a laboratory for the investigation of the chemical and physical problems which may come up in connection with the works, and it has been the speaker's duty to collect and examine a large number of aggregates which may be available for construction purposes at various points along the route of the proposed aqueduct.

What is here presented contains nothing original as to method, but is simply the application of the methods proposed in this paper to a few aggregates as they have been found. These methods are shown by the diagrams, Figs. 17 to 21, inclusive. The calculations used in combining the curves have been omitted. The methods by which this is done are not difficult, and are very fully explained in "Concrete, Plain and Reinforced," by Messrs. Taylor and Thompson, in the chapter on proportioning concrete written by Mr. Fuller.

* This discussion (of the paper by William B. Fuller and Sanford E. Thompson, Members, Am. Soc. C. E., printed in *Proceedings* for March, 1907), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Davis.

The diagram, Fig. 17, is a study of crushed rock, the mechanical analysis having been made and plotted in the manner previously described. This rock is the Shawangunk grit, which is a quartzite. The lower curve shows the analysis of the material as it came from the crusher, ranging in size from $\frac{3}{4}$ in. down. The upper curve shows the same material run through rolls set $\frac{1}{8}$ in. apart.

The ideal curve is shown as a dotted line. This curve was plotted by using the constants given for Jerome Park crushed stone, that stone being taken as representative of crushed rock in general,

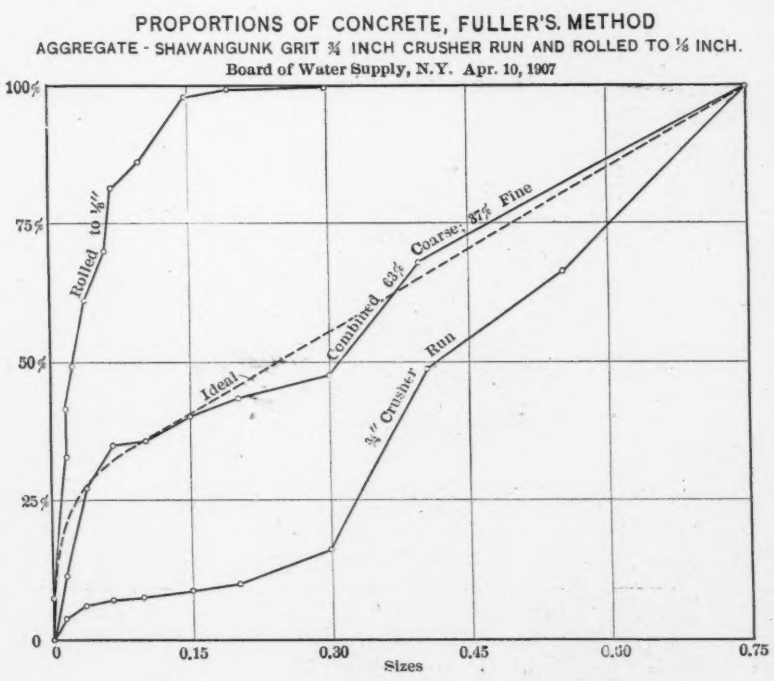


FIG. 17.

as far as the constants are concerned. The combined curve shows the result of combining the two sizes of materials in the proportions of 63% coarse and 37% fine. The resulting curve conforms closely to the ideal down to stone of 0.4 in. diameter. From this size down to that of 0.15 in. diameter, there is a deficiency. Of course, this could be remedied by combining the different proportions, which would raise the combined curve.

One of the conclusions of the paper, however, is that a deficiency in the medium-sized stone will not result in a loss of

Mr. Davis. strength in the concrete, while an excess will cause such a loss; therefore, it is better not to change the proportions. The combined curve also shows a deficiency in the quantity of fine sand, but this will be made up by the addition of the cement, as the ideal curve includes the cement; and, with the cement added, there will be a new or corrected combined curve, for the sand portion, which will approach the ideal. This case is a very ordinary one.

Fig. 18 shows a gravel. The run of the bank is plotted, the lower and upper curves showing the result of screening this material to two sizes—that which is retained on a sieve of 0.2-in. mesh, or clear opening, and that which passes such a sieve.

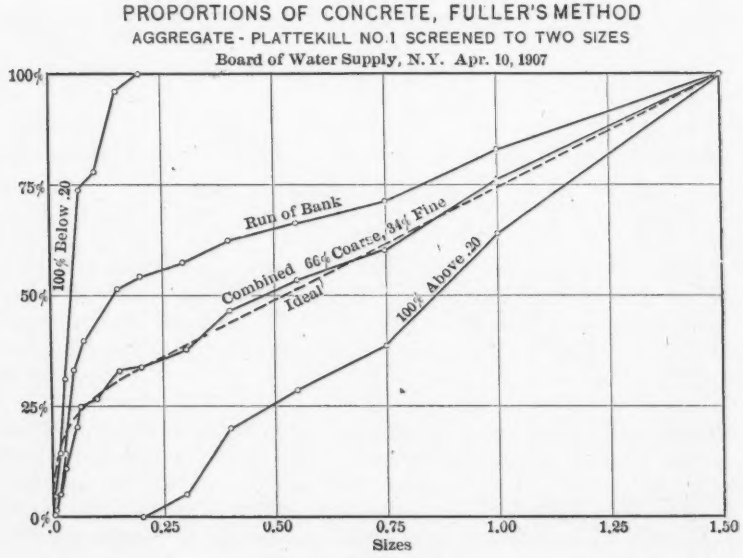


FIG. 18.

The ideal curve was plotted with the constants given for Cowe Bay gravel, and shows, by the length of the ordinate at 0.2-in. diameter, that 66% of the ideal mix should be coarser than this. The combined curve shows the result of taking this percentage of coarse material and 34% of fine material. It approaches very closely the ideal mix. There is a deficiency of fine sand, but, as in the case of the Shawangunk grit, this would be made up by the cement.

Fig. 19 shows a crushed limestone, available in the New York market. The lower curve shows the product sold as 2½-in. stone.

Mr. Davis.

It ranges, actually, from 2 in. to ¾ in. Such stone is often used, with screenings, as a substitute for sand. The upper curve shows such a material produced by a crusher with jaws set to the maximum opening of ¼ in.

In these experiments, the two combined curves show how, by scientific study, improvement may be made over the usual rule-of-thumb methods of mixing. Suppose a concrete having the proportions, 1 cement to 8 aggregate, is wanted. In ordinary work a common proportion would be 1 : 2½ : 5½. This is equivalent, in this case, to 60% of coarse and 40% of fine aggregate. The plotting shows a deficiency in all sizes below those of about 1¼ in. diameter. An improvement is shown by the upper combined curve in proportions of 49% coarse and 51% fine aggregate, and the case involves

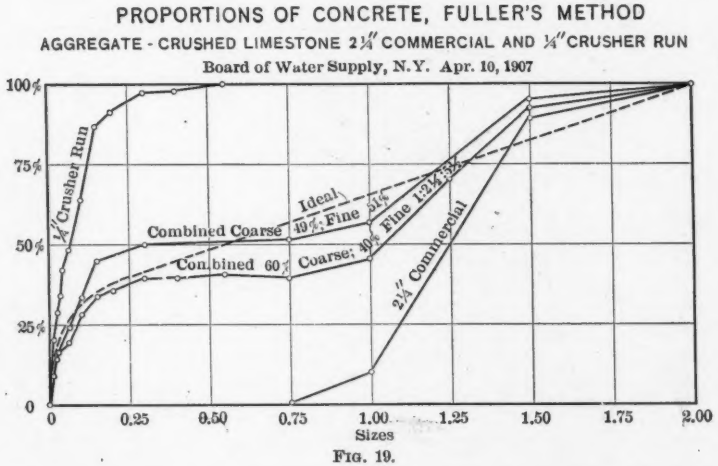


FIG. 19.

no extra expense for labor, but the cost might be increased somewhat by the use of the increased proportion of fine material, as it is more expensive to crush it to this fine size.

Fig. 20 shows a gravel from Cortland, N. Y. It was not selected because it illustrated particularly the application of this method of proportioning, but because it is one of the best gravels to be found in the vicinity where it occurs.

Concrete is often made by mixing a certain proportion of cement with gravel, as it comes from the bank. A comparison of the curve of the run of the bank with the ideal curve shows how far from good the results would be in such a case.

The upper and lower curves show the analyses of this material screened to two sizes, as shown in a preceding case. By the length

Mr. Davis. of the ordinate, at 0.2 in. diameter, the ideal curve shows that 66% of the mix should be coarser than this size.

The upper combined curve shows the result. This gives almost ideal results for the sand portion, but the proportions passing various medium-sized screens are altogether too large. The lower combined curve shows the result of attempting to remedy this by using a larger proportion of the coarse material. The stone portion of the mix is improved, but the sand portion becomes totally unfit. This demonstrates that this material screened to these two particular sizes cannot be combined in ideal proportions.

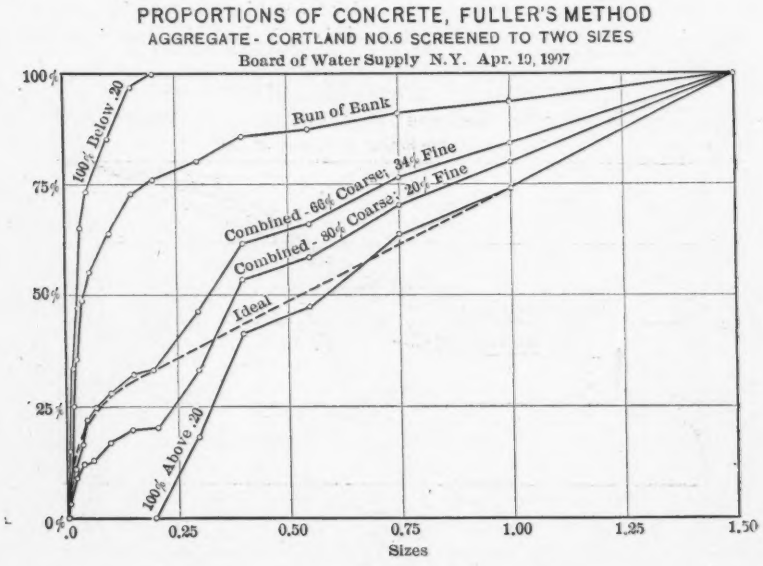


FIG. 20.

Inspection of the curve shows that the material retained above the 0.2-in. diameter conforms closely to the ideal down to 0.4-in. diameter, and that the trouble with the combined curves occurs between 0.2 and 0.4 in. diameter. This suggests screening the material into three instead of two sizes. The result is shown by Fig. 21, on which the run of the bank, the ideal curve, and the material below the 0.2-in. size are plotted, as in Fig. 20. The coarse material has been separated into two sizes, ranging from 0.4 in. up, and from 0.2 to 0.4 in.

The combined curve shows the result of combining the three sizes in proportions of 56% coarse, 34% fine, and 10% medium.

The result is a close conformation to the ideal curve, and it might be safely stated that the resulting concrete would be strong and economical. Mr. Davis.

It would not be at all impracticable to use these proportions, as it would only be necessary to interpose another screen of about $\frac{3}{8}$-in. mesh, when screening out the sand from the run of the bank.

The authors explain the methods of making laboratory comparisons of the different aggregates and studying the various mixtures, but these do not conflict with the more common ones used for determining the proportions of voids in the aggregate; they simply accomplish the same result in a more accurate and scientific way.

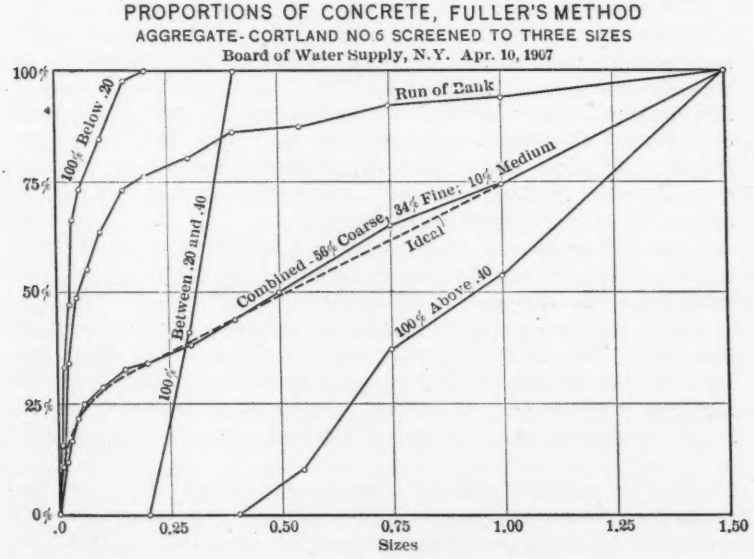


FIG. 21.

H. DE B. PARSONS, M. AM. SOC. C. E.—The speaker would like to ask the following questions: Mr. Parsons.

Did the experiments show any limit to the tensile stress to which concrete might be subjected with safety? There are masonry structures in which the masonry oftentimes is under tension, but do the experiments show any limit in that direction?

Did age affect the concrete in any way? Frequently, a cement which has a certain strength at the end of a given time, say 1 month, or 2 months, is not as strong at the end of an extended period as another cement which is weaker at the end of the same

Mr. Parsons. first period of 1 month, or 2 months. Has this difference in strength any marked effect when the aggregate is mixed as suggested in the paper? Were any experiments made along this line?

Was the effect of heat studied? In other words, would a concrete mixed according to the ideal curve resist heat any better than a concrete in which the same materials were used, but not mixed according to the ideal curve?

Mr. Hazen. ALLEN HAZEN, M. AM. SOC. C. E.—All who use concrete are interested in the art of selecting and mixing the ingredients in such a way as to get the best results; and a better understanding of the underlying principles is certain to be helpful in many cases in obtaining a better utilization of available materials.

There is some comfort to be drawn from the paper, and especially from Mr. Davis' discussion of it, in regard to the methods which have been in use. Mr. Davis, in his diagrams, has designated the various materials as "coarse" and "fine," and it is noted that, as he computes, he gets the best results in nearly all cases when about one-third of the whole volume is made up of fine material. Now, one-third of sand is not very far from the proportion which is generally used in making concrete, and it appears that this analysis does not tend to change this proportion.

The authors contend that, by using a theoretically correct mixture—and by theoretically correct is meant the kind of a mixture which they describe—about 12% of the cement can be saved, as compared with a concrete mixed in the ordinary way from average materials. That is to say, with concrete mixed in the usual way, from good materials, but without any special precaution, it would take 12% more cement to produce a concrete of the same strength as could be obtained by the use of especially prepared and selected mixtures.

Now, in mixing ordinary concrete, at current prices for materials, and with an average mixture, 12% of the cement probably represents 25 cents per cu. yd.; and the question is raised as to whether the additional grading, mixing, and supervision required to get the ideal mixture can be carried out for as little as 25 cents per cu. yd. In other words, can the saving in cement be made to pay for the extra trouble in connection with the other materials? Obviously, this will depend upon conditions. There will certainly be many cases where an improvement in the mixture can be obtained at an expense so small that the saving in cement will more than justify it; but there will be other cases, and many of them, where it will be cheaper and better to use the additional cement than make the extra effort to secure what the authors consider an ideal arrangement of the other ingredients.

The paper certainly will help to an understanding of what is

desirable; and "knowing what is wanted" is a long step toward securing it. The authors have certainly helped in that direction, and are to be congratulated. Mr. Hazen.

SAMUEL TOBIAS WAGNER, M. AM. SOC. C. E. (by letter).—This paper is of scientific interest, and is particularly valuable on account of the accuracy with which the experiments were made and presented. Careful work of this kind must be done by someone, in order that principles may be established definitely; and, ordinarily, such care is impossible. After these laws are determined, all that remains is to ascertain the practical uses to which the conclusions may be applied. Mr. Wagner.

After reading the paper carefully and listening to Mr. Thompson's able abstract and Mr. Davis' timely discussion, the writer is fully convinced that the constructing engineer on any work of magnitude should know, with the materials which he has on hand, whether he is using the best, or nearly the best, proportions of the aggregates, in order to produce the best concrete. In many cases the stone will come from the same quarry, be passed through the same crusher and screens, and the sand will probably not vary to any great extent unless the locality from which it is obtained is changed. The engineer, therefore, should be in a position—if it can be done without the expenditure of too much time—to know what proportions of each of these given materials will give the best results. Usually, he cannot afford the time to make a laboratory test, in a manner similar to that used by the authors, in order to see what kind of a curve his materials will give, but it would be a great satisfaction to him to see such a curve.

The authors used 21 sieves in their tests in order to determine accurately all points on their curves. It was undoubtedly wise to use this number in such experiments, but when applied practically it means that such a determination must be made in the laboratory. The writer would like to ask the authors whether it is not possible to reduce the number of these sieves to, say, four or five for the sand, and to a similar number for the stone? Could not these be taken into the field, with a weighing scale, so that an approximate curve might be determined there which would be of value?

If such a field outfit would enable an engineer to determine an approximate curve, it would not be a serious matter to go through the operation whenever the sizes of the sand or stone seemed to vary.

The engineer must determine from these results whether he is warranted in making any change which would entail additional cost, but, in most localities, the mere re-proportioning of the aggregate, without making any change in the proportion of the cement to the total aggregate, would entail no additional expense except the adjustment of the mixing boxes, and would, without doubt,

Mr. Wagner. make considerable difference in the character of the resulting concrete.

In recent years, the writer's attention has been called to the materials furnished on a number of works where the specified dividing line between the sand and the stone was ¼ in. In most of these cases the stone represents the "run of the crusher," and while not nominally containing any material smaller than ¼ in., actually had an amount of finer material. On the other hand, the sand contained some material which was larger than ¼ in., and yet the proportioning was made without any reference to the actual sizes. It seemed self-evident that there was too much so-called "sand," and not enough "stone," that is, there was an excess of fine material in the concrete.

The authors are asked whether they cannot suggest some satisfactory method to be used in the field which would enable the engineer on the ground to determine what changes, if any, should be made in the aggregates of the mix. Such a method, if practicable, would seem to have all the elements of scientific reasoning, and the small additional expense involved would be warranted on a work of any magnitude.

If, however, the results were to show that a re-crushing of the stone or a re-sieving of the sand were advisable, the question of the additional cost must govern the decision as to whether it would or would not be economical.

Mr. Feret. R. FERET,* ESQ. (by letter).—The writer has read this noteworthy paper with especial interest, as the methods followed by these investigators have been worked up in a spirit similar to that by which he himself has been animated; in fact, this study of concretes might be considered as a continuation of his own work on mortars. For example, he has already graphically represented the composition of granular mixtures, such as sand and gravel;† has instituted the calculation of the elementary volume and the density of mortars;‡ has insisted on the marked difference in the proportion of voids existing in the same mixture when dry and after gauging with water;|| and has shown that the volume of cement ought to be taken into account in the expression of the granulometric composition of the mixture, and that this latter is not modified by replacing a part of the cement with an equal absolute volume of sand of the same fineness, from which he draws the conclusion that the best granolithic composition is that which after gauging gives the densest mortar, the strength being governed by the proportion of fine grains as represented by the cement.§

* Ancien élève de l'Ecole Polytechnique; Chef du Laboratoire des Ponts et Chaussées à Boulogne-sur-Mer.

† Commission des Méthodes d'Essai des Matériaux de Construction, Tome IV, p. 309.

‡ Sur la compacité des mortiers hydrauliques; *Annales des Ponts et Chaussées*, 1892, II, p. 50.

|| Chimie appliquée à l'Art de l'Ingénieur, 2d edition, p. 741.

§ *Annales des Ponts et Chaussées*, 1892, II, pp. 57 et 157.

Mr. Feret.

The writer is very much honored by the consideration which the authors have shown for his former works; as the basis of their researches rests precisely on the agreement in principles which have just been mentioned, he highly esteems the work of these investigators, and the remarks which he presents apply only to points of detail.

(a).—First, he believes that instead of using sieves with square meshes to determine the different sizes of grains, it would have been preferable to use metal sheets perforated with circular holes, these being simpler to define, less likely to be deformed, and more easily standardized. There exists, moreover (at least for the medium and large grains of sand), the simple relation, $x = \frac{3}{4}d$, between the diameter, d, of the holes in the sheet metal and the size of the square mesh of the sieve which, with any ordinary sand, passes the same proportion of residue.

(b).—From the fact that most concretes contain the same relative proportions of cement and aggregate, it results that the densest concretes contain, in an equal volume, more cement than the others, which explains in part their usual superiority in strength. To show in a better way that this superiority is due also to the density itself, it would have been preferable to have used in each such quantities of cement (calculated after the preliminary tests for density) that the weight of the cement entering into the same volume of set concrete would have remained constant.

(c).—Concerning the difference in compacting which may result from more or less energetic ramming, it would have been well to determine the density on the blocks themselves before using them for strength tests. In reality, errors committed from the omission of this precaution are probably slight, for it seems that the concretes tested were all of a rather wet consistency. The effect of the ramming would be more important with dry concrete. On the other hand, it must not be forgotten that an increase in the proportion of water for gauging favors settling in lean concrete, so that laws resulting from the comparison of concretes mixed wet do not necessarily apply to those of dry consistency.

(d).—The transverse tests give a poor idea of the strength of the concrete, for the rupture depends chiefly on the composition of the concrete near the surface of the prism under tension, and, with a mixture having coarse ingredients, the distribution of these is far from being the same against the walls of the mould as in the interior of the mass.

(e).—As the authors have well illustrated in Table 7, the tests for compression on fragments of beams having their ends coated with neat cement show too great a strength. The experiments noted in Table 24, on cubes of mortar 71 mm. (2.8 in.) on a side, show that even a slight covering of mortar applied to the com-

Mr. Feret. pressed faces of a block increases or diminishes its resistance according as the mortar is stronger or weaker than the block.

TABLE 24.

Description of specimens tested.	Average strength, in pounds per square inch.*
I.—Blocks Broken after Hardening Twenty Weeks.	
A. Blocks made wholly from mortar of test	1 250
B. Blocks in which the mortar had been replaced by a leaner mortar with a thickness of 0.119 in. on one of the compressed faces	1 210
C. Similar blocks with 0.590 in. of lean mortar	1 040
D. Similar blocks with 0.119 in. of neat cement	1 320
II.—Blocks of Another Mortar Tested at the End of Four Weeks.	
E. Blocks without caps	1 095
F. The same blocks, covered with a very thin coat of neat cement	1 250

* Each strength is the average of six tests.

In regard to the fragments of prisms tested by the authors, it is conceivable that the irregularity of their ends, notwithstanding the caps of neat cement, might have made the decidedly large difference between the strengths obtained, as appears from the averages found, 14.4% and 4.5%, respectively, for these variations. These difficulties might have been avoided and more exact results obtained by crushing the prisms transversely, placed cross-wise between two steel plates of the same size as the prisms themselves, the irregular ends extending from each side and exerting no influence on the strength of the cubic blocks actually submitted to the compression.

(f).—The writer does not think justifiable the distinction, made in Columns 23 and 24 of Table 8, between the voids of the cement and those of the aggregate, for the separation of the grains of cement in the mortar or in the concrete is not the same as in the neat cement paste. It would be more interesting to try to separate the total voids into "pores" of very small dimensions, produced by bubbles of air entrained in the mortar, or by the departure of the water in so far as it combines and evaporates, and "cavities," or relatively large voids, resulting from an incomplete filling of the spaces between the stones by the mortar. But the difficulty is to determine a limiting size between the grains which may be considered as forming part of the mortar and those which should be considered as stone.

(g).—The law discovered by the authors from which the maximum density of all concretes made with given materials corresponds to its granulometric composition defined by a certain curve, is ex-

tremely interesting. Unfortunately, it is necessary to determine for each kind of material the two parameters, a and b, which measure the axes of the ellipse, and, moreover, it seems to result from the reported experiments that the concretes corresponding to the theoretical curve often have too little cement to be used in practice. Finally, the authors' Conclusion 7, in connection with their statement that stones of uniform size give concrete at least as dense as stones of graduated sizes conforming to the rectilinear part of the theoretical curve, suggests that the actual formula is not definite enough, and should be replaced by another, more general and more simple. Particularly, it is desirable that new researches be undertaken, with the same care and the same earnestness, with a view to finding a law applicable to materials separated only into a limited number of sizes of grains. Mr. Feret.

(h).—Experiments upon permeability give in general uncertain results, and it is not unusual to see many blocks of the same concrete which, although treated in an identical manner, permit very different quantities of water to filter through them. Moreover, the flow varies very rapidly at first, each time that water at a higher pressure is applied. This law is not brought out clearly from the authors' tests, and Table 21 seems even to contradict it. It can be verified by the following experiment which the writer has made, on two concretes, A and B, after various durations of storage in moist air, with each of which three identical sample blocks had been made. These samples are distinguished from one another in Table 25 by the indices. Moreover, Table 25 confirms the law indicated in the paper that the flow seems to be very nearly proportional to the pressure.

In all the experiments in Table 25 the pressure was maintained for a certain time at 20 kg. (284 lb. per sq. in.) between the next to last reading and the last, and the flow, almost always, was much diminished. In Table 26 it has been taken at an interval of 29 kg. (412 lb. per sq. in.), and then brought back to 20 kg. (284 lb. per sq. in.). It is noticeable then that the permeability increased as if the effect of the momentary increase of the pressure had been to open new passages for the water, or partly to clear out the passages already existing.

The principal conclusion to be drawn from the experiments in Table 26 is that in the quantity of water flowing through the same block during a unit of time there may be considerable variation, according to the conditions of time and pressure under which the previous filtration was carried on. At this place it may be proper to remark that, in Column 17 of Tables 18, the authors have neglected to indicate the pressure maintained up to the first appearance of the filtering water.

TABLE 25.—PERMEABILITY TESTS.

Age of blocks.								
	Pressure of water, in pounds per square inch		284	213	142	71	284	284
5 days....	Time of flow after commencement of test,* in minutes		20	28	36	45	60	180
	Block A_1†							
	Block B_1	Flow during 5 min., in grams	875	620	389	184	720	495
		Flow per minute, and per pound pressure — Each test	0.616	0.582	0.548	0.518	0.507	0.349
		Flow per minute, and per pound pressure — Average			0.554			0.349
29 days....	Time of flow after commencement of test, in minutes		200	215	230	240	255	375
	Block B_1	Flow during 5 min., in grams	67	47	30	15	64	48
		Flow per minute, and per pound pressure — Each test	0.047	0.044	0.042	0.042	0.045	0.034
		Flow per minute, and per pound pressure — Average			0.044			0.034
30 days....	Time of flow after commencement of test, in minutes		85	95	105	120	135	255
	Block A_2	Flow during 5 min., in grams	38	28	18	10	40	43
		Flow per minute, and per pound pressure — Each test	0.027	0.026	0.025	0.028	0.028	0.030
		Flow per minute, and per pound pressure — Average			0.027			0.030
	Block B_2	Flow during 5 min., in grams	229	172	115	55	221	189
		Flow per minute, and per pound pressure — Each test	0.161	0.162	0.162	0.155	0.156	0.133
		Flow per minute, and per pound pressure — Average			0.159			0.133
1 year....	Time of flow after commencement of test, in minutes		100	109	119	129	139	150
	Block A_3	Flow during 5 min., in grams	580	310	160	67	390	285
		Flow per minute, and per pound pressure — Each test	0.409	0.291	0.225	0.189	0.275	0.201
		Flow per minute, and per pound pressure — Average			0.278			0.201
	Block B_3	Flow during 5 min., in grams	450	320	205	198	410	395
		Flow per minute, and per pound pressure — Each test	0.317	0.300	0.289	0.276	0.289	0.278
		Flow per minute, and per pound pressure — Average			0.294			0.278

* In most of these tests the pressure of 284 lb. was reached at the end of about 15 min.
† At a pressure of 128 lb., water was forced through Block A, in large streams, and it was necessary to discontinue the tests.

Mr. Feret.

Mr. Feret.

TABLE No. 26—PERMEABILITY TESTS.

Age of blocks.	Pressure of water, in pounds per square inch.....	284	213	142	71	284	412	284	General Average.
	Time of flow after commencement of test, in minutes.	120	131	141	151	165	180	190	
1 year.....	Block B_1. Flow during 5 min., in grams.....	108	77	49	24	95	158	97	
	Block B_1. Flow per minute per pound pressure..	0.076	0.072	0.069	0.068	0.067	0.077	0.068	0.071
	Block A_2. Flow during 5 min., in grams.....	177	140	100	59	158	234	162	
	Block A_2. Flow per minute per pound pressure...	0.125	0.132	0.141	0.166	0.111	0.114	0.114	0.129
	Block B_2. Flow during 5 min., in grams.....	165	119	77	38	153	260	157	
	Block B_2. Flow per minute per pound pressure...	0.116	0.112	0.108	0.107	0.108	0.126	0.111	0.113

Mr. Feret. The writer has recently been informed of experiments on the continued filtration of sea water through mortars, from which he concludes that it is often the case that the important initial diminution of permeability will be followed at the end of 8 or 10 days by a slight and temporary increase, and, with the method of conducting the experiments on the same subject,* which he has previously published, this might easily have passed unnoticed. He will be interested to know if some other investigator has not also observed this phenomenon.

* *Annales des Ponts et Chaussées*, 1892, II, p. 97.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

JOHN JAMES ROBERTSON CROES, Past-President, Am. Soc. C. E.*

DIED MARCH 17TH, 1906.

Not many years ago Civil Engineering was unrecognized as a profession, and its few practitioners were not theoretically educated as engineers, but gained their technical education from study, example, and practical experience, much in the same manner as the apprentice learns a trade.

Engineering schools were unknown, and scientific courses in colleges not yet established. In those days, however, there were engineers who cast luster upon the nascent profession—men who, although not so highly educated as specialists, had a much broader general education than the average graduate of the modern schools of engineering, and responded admirably to the exigencies of new and great public works.

John James Robertson Croes was one of the latter class, and one of the brightest of these engineers of the old school. Broadly and thoroughly equipped in general scholarship, he entered the profession at the lowest round of the ladder, and fitted himself by special study and practical experience for a long career of usefulness.

He was the only son of the Rev. Robert Brown and Helen (Robertson) Croes, and was born in Richmond, Virginia, on the 25th day of November, 1834.

At the time of his birth his father was the rector of St. John's Church in Richmond. His paternal grandfather was John Croes, first Bishop of New Jersey, whose parents came from Holland.

His maternal grandfather was James Robertson, a Scotchman, who came to this country at an early age, and became a prominent and highly respected citizen of Philadelphia.

To Bishop Croes may properly be ascribed the successful establishment of Rutgers College, prior to 1825 known as Queens College. This institution, projected in 1767 by the "Coetus" party of the Dutch Reformed Church, held a precarious and languishing existence, in fact, but a nominal one, from 1794 until 1801. During the latter year the Rev. John Croes was called to the rectorate of Christ Church, New Brunswick, and, in addition, was

* Memoir prepared by the following committee: Edgar B. Van Winkle, Rudolph Hering, and Charles Warren Hunt, Members, Am. Soc. C. E.

simultaneously invited by the trustees of Queens College to reopen that institution by establishing and taking charge of its Grammar School. When, after six years, he resigned, the school had become so well founded and prosperous that the trustees determined that, under the old name of Queens College, they would enlarge its scope and reinstitute a complete collegiate course.

Bishop Croes was a veteran of the Revolutionary War, having served three years in the army when a young man, respectively as private, sergeant, and sergeant major, and it is interesting to note that he is the only person rising to the Episcopate in the Protestant Episcopal Church who ever served in the Continental Army.

The boyhood of the subject of this memoir was passed at Richmond, Virginia, and at Terre Haute, Indiana, to which place his family moved in 1843.

His father—a fine classical scholar—prepared him thoroughly for college, imparting to him in a strong degree his own literary tastes, and laying the foundation for his excellence as a writer.

Mr. Croes in 1850 entered the College of St. James, in Hagerstown, Maryland. On his journey there from Terre Haute, the first seventy miles had to be made, over the National Road to Indianapolis, in a heavy, canvas-covered box wagon, without springs, and drawn by four horses. Indianapolis was at that time the western terminus of the then recently constructed Richmond and Indianapolis Railroad.

He was graduated from the College of St. James in 1853, and at once began the study and practice of civil engineering. This action was much regretted by some of his relatives, who felt that such an "occupation" was unworthy of his fine equipment of intellect and education, which should have been reserved for one of the "three learned professions."

His first employment was in 1854, in New Brunswick, New Jersey, with Israel Smith and Peter Sours upon surveys for the Newark and Bloomfield Railroad, and with the New Jersey Railroad and Transportation Company.

His fine natural abilities and industry were even then so conspicuous that he was selected by the late James P. Kirkwood, Past-President, Am. Soc. C. E., as an assistant on the construction of the first water-works for Brooklyn, New York, and finally placed in charge of the construction of the main reservoir and pumping station at Ridgewood.

In 1860 he took service under another of our Past-Presidents, the late Alfred W. Craven, then Chief Engineer of the Croton Aqueduct Department, of New York City, and was detailed as Principal Assistant to still another of our Past-Presidents, the late General George S. Greene, on the Croton Water-Works Extension,

his work being mainly on the construction of the large reservoir and appurtenant works in Central Park, and of the so-called High Bridge Enlargement.

General Greene, being called to service in the War of the Rebellion, was succeeded by the late William L. Dearborn, M. Am. Soc. C. E., who had been Resident Engineer on the High Bridge Enlargement, and, in turn, Mr. Croes was promoted to that position and completed the work.

From 1863 to 1865 he was Principal Assistant Engineer on the Water-Works of Washington, D. C., and had charge of completing its Aqueduct, and the famous Cabin John Bridge, as well as building the dam at Great Falls on the Potomac River. During some five months in 1865 he assisted his old chief, Mr. Kirkwood, in examining and designing improvements for the water supply of both Cincinnati and St. Louis.

In 1866 he was Principal Assistant Engineer to General Greene in designing and constructing the first of the storage reservoirs to be built in connection with the Croton River water supply of New York City.

The dam of this first reservoir, situated at Boyd's Corners, Putnam County, New York, is 78 ft. high and 670 ft. long, and was unique, as far as America was concerned. At that time, nothing on high masonry dams had been published in the English language. About six months after work began, General Greene was called away to assume the position of Commissioner and Chief Engineer of the entire Croton Aqueduct Department, and Mr. Croes was placed in charge of the Boyd's Corners Dam, which he practically completed in 1870, at which time, the Tweed régime having been inaugurated, men of strict integrity and strength of character were an inconvenient factor, and General Greene and Mr. Croes were quickly required to make room for more congenial officials.

In 1872, George H. Norman, M. Am. Soc. C. E., had presented a fund to the Society to provide a gold medal to be awarded annually to the paper which should be judged worthy of special commendation as a contribution to engineering science. The first award of this medal was made to Mr. Croes for his paper descriptive of the Boyd's Corners Dam, entitled "Memoir of the Construction of a Masonry Dam."*

In 1870, upon retiring from the position of Resident Engineer of the Boyd's Corners Dam, Mr. Croes became Principal Assistant to William H. Grant, M. Am. Soc. C. E., in the work of laying out street, sewerage and water systems for that portion of New York City north of 155th Street, as well as certain parts of Westchester County.

* *Transactions*, Am. Soc. C. E., Vol. III, page 337.

In 1872, upon the retirement of Mr. Grant, Mr. Croes was appointed Topographical Engineer of the newly created Department of Public Parks, charged with laying out a system of streets, parks, etc., for the newly annexed portion of New York City, embracing some 12 300 acres beyond the Harlem River.

The City of New York, at this critical period in its development, was fortunate in securing the services of a man, so able, original, and intelligent, and with the courage of his convictions.

The commissioners who laid out New York in 1811 had adopted a most crude arrangement of streets and avenues, all at right angles, without regard to the topography of the land subdivided or the convenience or rights of the general public. Mr. Croes used the rectangular system of streets where it was economical and convenient, but did not hesitate to replace it by one adapted to the topography, and introduced curved avenues where the grades or the cost of grading could be reduced thereby. From æsthetic consideration, as well as those of utility, he first introduced systems of parkways connecting well-defined centers.

For this departure from the extravagant system of inflexible rectangularity, Mr. Croes was subjected, more or less, to ignorant criticism, and in some cases to the active hostility of land owners who were wedded to the awkward lot unit of 25 by 100 ft.

Being clear as to the correctness of his views, he was not a man to present plans inspired by considerations of temporary expediency. Time has justified his wise foresight, and those portions of the "Annexed District," where his original plans have actually materialized, are more attractive and convenient than any location in the rectangular districts having similar natural topography.

In 1879, Mr. Croes resigned from service in the Department of Public Parks, and thereafter, to the end of his life, devoted himself to developing a private practice, initiated in 1870, in connection with the firm of Croes, Church and Van Winkle. Henceforth, his high professional ability and ripe experience became more and more known; and his work developed largely into that of consultation on matters of hydraulic engineering. His reputation in this capacity was so widespread that he received calls from all parts of the country.

The water supply of Newark, New Jersey, was the subject of an exhaustive examination and report in 1879, and later, for the Lehigh Valley Railroad Company, he conducted extensive investigations which resulted in the execution of a contract for supplying water for Newark, since carried out by another company.

As a notable exception to his consultation practice, he served as Chief Engineer of the Suburban Rapid Transit Company, from its formation until its merger with the Manhattan Company in 1891. Under his supervision some four miles of elevated railroad

were built, including the large draw-bridge across the Harlem River at Second Avenue. An unique feature of this road—one strongly advocated by Mr. Croes—was the purchase of a right of way through private property.

In 1889, Mr. Croes made extensive examinations relative to the water supply for Syracuse, New York, and his recommendations and plans, embodied in a valuable report, were adopted and subsequently carried out.

In 1889 he was one of a Board of Experts to report on the Quaker Bridge Dam for the Croton Aqueduct Commission.

In 1899 he prepared for the Comptroller of the City of New York a report on the New York Water Supply; and in 1900 another for the Merchants' Association on the same subject. In these he pointed out the waste of water constantly going on in the city, and urged the necessity for a more general use of water meters.

In 1901 he served as a member of a Board of Consulting Engineers which prepared a report for the Croton Aqueduct Commission on the New Croton Dam and Reservoir.

He prepared, and in several cases carried out, plans for water supply, sewerage, etc., for many small cities, among them those for Lancaster, Pennsylvania, and Lawrenceville, New Jersey.

In 1895, Governor Morton appointed him as one of the Commissioners for the Preservation of the Palisades. He was a most interested enthusiast on this subject, and, although serving without remuneration, threw himself into the work with great energy, sparing neither time nor expense to promote the salvation of this magnificent monument of Nature.

From 1903 to 1905, he served as Consulting Engineer for the New York State Health Department, and in this capacity investigated and reported upon many technical questions.

From 1903 to his death, which occurred just as the work was on the threshold of completion, Mr. Croes was engaged as Engineer of the Construction of the Artificial Lake for Princeton University. At the exercises marking the formal presentation of the lake to the University, President Wilson voiced the sentiment of many when he said:

"I deeply regret the fact that Mr. Croes, the distinguished engineer who devoted himself with so much interest to the execution of this public project, did not live to see its happy completion."

In 1897 a sudden and severe illness prostrated Mr. Croes, and from that time until his death, which occurred on the 17th day of March, 1906, he was never a well man, yet he continued to work indefatigably to the end.

This sketch, which is rather a suggestion than a statement of the work done by Mr. Croes during his fifty years of professional

life, would be incomplete without reference to his literary achievements. He wrote easily and well on technical and general subjects. He contributed largely to the editorial pages of *The Sanitary Engineer* (now *The Engineering Record*) during some ten years, and for many years compiled the "History and Statistics of American Water-Works," published by *Engineering News*. He also contributed to *The Railroad Gazette* notable articles on Rapid Transit, reviews of scientific books to the *New York Times*, and prepared many professional papers for the technical societies of which he was a member. He was also the author of a number of articles for "Johnson's Universal Cyclopedia." Among his literary accomplishments was also a poetical ability, which, however, was rarely revealed, and then only to a few intimates.

Upon the reorganization of the American Society of Civil Engineers in 1867, after a dormant period of fifteen years, Mr. Croes was among the first of the younger engineers elected to membership, and throughout the rest of his life he was devoted to its welfare, a conspicuous, enthusiastic, and hard-working member.

Without detracting from the memory of any of the great men who laid the foundation for and started the upbuilding of this Society, it can be truly said that to no one is it more indebted for faithful service and undeviating loyalty than to the subject of this memoir. He served as a Director in 1877, as Treasurer from 1878 to 1887, as Vice-President in 1888, and as President in 1901. As a Past-President he continued to serve as a member of the Board of Direction until his death, and such was his devotion to the Society that, unless restrained by illness, he never failed to attend the meetings of the Board. In 1881, without compensation or assistance, he prepared a catalogue of the railroad section of the Library, consisting of a volume of 188 pages.

Mr. Croes was also a Member of the Institution of Civil Engineers of Great Britain, of the American Public Health Association, and the American Water Works and the New England Water Works Associations.

He was by nature a man of essentially social tendencies, the indulgence of which was limited and constrained by the exigencies of an unusually active professional life. Of fine intellectual gifts, broad education, acquaintance with literature, varied experience with many classes of men, united with a retentive memory and keen sense of humor, he was always an attractive talker.

These qualities, combined with buoyancy of spirits, made him as a young man a delightful comrade, and when ripened with years a most interesting and instructive companion. Euthusiasm in regard to whatever matter he took up, either of professional work, recreation, or controversy, was a dominant feature in his character,

and made him a potent advocate and natural leader. He was a good linguist and a discriminating lover of music and art. His Scotch and Dutch ancestry made him a man of positive convictions, and tenacious of his views when once carefully established. When led into controversy, he was a formidable opponent, while, as a friend, he was most steadfast and loyal.

A well-founded confidence in his own mental equipment made him largely free from self-consciousness, and he was a good expert witness, the subject in hand monopolizing his thoughts without embarrassment as to the impression, favorable or unfavorable, he might be making.

He joined the Union League Club in 1869, and, later, naturally gravitated to the congenial intellectual atmosphere of The Century Association, to which club he was elected in 1884, and where he was ever a welcomed and valued member. At the time of his death he was serving as a member of its Committee on Admissions.

Of all the phases of Mr. Croes' life, the one least known to the world at large, but one that was finest, as seen by his intimates, was his domestic life. His spirit was true altruism. He never married, and his devotion to his family can only be described as beautiful. Nothing he did for them was ever felt as a sacrifice. His happiness was only reached through their happiness. Such affection was warmly reciprocated, and his home was made for him a place of charm as well as rest.

In analyzing the life and character of Mr. Croes, two elements are always distinctly traced: strength and intellect. As a young man, he was strong physically, but as conditions changed with age, this attribute greatly lessened, but his mentality seemed to gain more than his physical strength lost.

His power of mind and body was shown in his remarkable capacity for concentration and the accomplishment of work. His reports were always based on the most extensive statistics and sets of observations available, all elaborated and collated with unlimited labor, so that the conclusions reached were clear and logical, and hence convincing. The rapidity of his work was due in a large measure to his power of concentration, to system, and to his habit of economizing time. As an instance of this habit, the paper for which he received the Norman Medal was largely written on scraps of paper while waiting for railroad trains.

He was honest—as befitted a strong man—and no considerations of policy or fear of consequences ever made him swerve in demanding honest work from contractors. His life, in this respect, could be held up to our younger engineers as an example.

His strength made him positive in his convictions, and strenuous in maintaining them, and sometimes led to strong antagonisms.

Although at times an active partisan, he was always an honest antagonist, fighting openly and never striking in the back.

In his business dealings it may be said of him as was said of another distinguished member of this Society: "He was not only straight from a business point of view, but he was morally straight." With his strength of character, self-respect and rugged honesty, he could never become a courtier, and the flattery he detested to receive he never thought to apply to others, not even in the form of studied deference which at times might have gained for him professional advantage.

His mind was so receptive that full advantage was easily taken of all opportunities for the acquisition of knowledge, which made him unusually conspicuous as a general scholar among professional colleagues. He kept in touch with the advancement of science and all questions of the day, and could intelligently appreciate and enjoy intercourse with men versed in the many forms of learning.

This, in brief, is the record of an eminent engineer, who for so many years has been a familiar figure at gatherings of the American Society of Civil Engineers, who held positions of trust in its management, who unstintingly worked for its welfare, who unselfishly helped to guide its policy from weak infancy to maturity and world-wide influence, and who loved it beyond all else save his family.

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Vice-Presidents.

Term expires January, 1908:	*Term expires January, 1909:*
ONWARD BATES,	JOHN A. BENSEL,
BERNARD R. GREEN.	JOHN A. OCKERSON.

Secretary, CHARLES WARREN HUNT.

Treasurer, JOSEPH M. KNAP.

Directors.

Term expires January, 1908:	*Term expires January, 1909:*	*Term expires January, 1910:*
AUSTIN L. ROWMAN,	GEORGE GIBBS,	ALLEN HAZEN,
MORRIS R. SHERRERD,	J. WALDO SMITH,	GEORGE W. TILLSON,
HEZEKIAH BISSELL,	EMIL SWENSSON,	FRANK W. HODGDON,
EDWIN A. FISHER,	JAMES M. JOHNSON,	JAMES CHRISTIE,
WILLIAM B. LANDRETH,	WYNKOOP KIERSTED,	HORACE E. HORTON,
GEORGE S. PIERSON.	WILLIAM B. STOREY, JR.,	ARTHUR L. ADAMS.

Assistant Secretary, T. J. McMINN.

Standing Committees.

THE PRESIDENT OF THE SOCIETY IS *ex-officio* MEMBER OF ALL COMMITTEES.

On Finance:	*On Publications:*	*On Library*
JOHN A. BENSEL,	MORRIS R. SHERRERD,	GEO. W. TILLSON,
GEORGE GIBBS,	ONWARD BATES,	H. BISSELL,
ALLEN HAZEN,	BERNARD R. GREEN,	JAMES CHRISTIE,
J. A. OCKERSON,	J. WALDO SMITH,	F. W. HODGDON,
GEORGE S. PIERSON.	EMIL SWENSSON.	CHAS. WARREN HUNT.

Special Committees.

ON UNIFORM TESTS OF CEMENT:—George S. Webster, Richard L. Humphrey, George F. Swain, Alfred Noble, Louis C. Sabin, S. B. Newberry, Clifford Richardson, W. B. W. Howe, F. H. Lewis.

ON RAIL SECTIONS:—Joseph T. Richards, C. W. Buchholz, E. C. Carter, S. M. Felton, Robert W. Hunt, John D. Isaacs, Richard Montfort, H. G. Prout, Percival Roberts, Jr., George E. Thackray, Edmund K. Turner, William R. Webster.

ON CONCRETE AND REINFORCED CONCRETE:—C. C. Schneider, J. E. Greiner, W. K. Hatt, Olaf Hoff, Richard L. Humphrey, Robert W. Lesley, J. W. Schaub, Emil Swensson, A. N. Talbot, J. R. Worcester.

ON STATUS OF METRIC SYSTEM:—Stacy B. Opdyke, Jr., John Waterhouse, D. A. Molitor.

ON ENGINEERING EDUCATION:—Desmond FitzGerald, Benjamin M. Harrod, Onward Bates, D. W. Mead, Charles Hansel.

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER.....5913 Columbus.
CABLE ADDRESS....."Ceas, New York."

Vol. XXXIII. AUGUST, 1907. No. 6.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

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MINUTES OF MEETINGS.

OF THE SOCIETY.

May 15th, 1907.—The meeting was called to order at 8.45 P. M.; Director G. W. Tillson in the chair; Chas. Warren Hunt, Secretary; and present, also, 156 members and 27 guests.

A paper by William H. Burr, M. Am. Soc. C. E., entitled "The Reinforced Concrete Bridge Across the Hudson River at Sandy Hill, New York," was presented by the author, and discussed orally by Messrs. E. W. Stern, L. L. Tribus, A. Atkinson, and D. W. Krellwitz. The Secretary presented a written communication on the subject from H. H. Quimby, M. Am. Soc. C. E.

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The Secretary announced the following deaths:

CHARLES HAYNES HASWELL, elected Member January 29th, 1868; Honorary Member May 12th, 1905; died May 12th, 1907.

NATHANIEL HENRY HUTTON, elected Member June 3d, 1896; died May 8th, 1907.

HIEL HAMILTON FILLEY, elected Member January 3d, 1883; died May 6th, 1907.

Adjourned.

June 5th, 1907.—The meeting was called to order at 8.40 P. M.; Director A. L. Bowman in the chair; Chas. Warren Hunt, Secretary; and present, also, 108 members and 18 guests.

The minutes of the meetings of April 17th and May 1st, 1907, were approved as printed in the *Proceedings* for May, 1907.

A paper by Arthur L. Adams, M. Am. Soc. C. E., entitled "A Solution of the Problem of Determining the Economic Size of Pipe for High-Pressure Water-Power Installations," was presented by the Secretary, who stated that he had received communications on the subject from Messrs. W. L. Butcher and W. E. Buck, but would not read them on account of their mathematical nature. The paper was discussed orally by Messrs. E. Kuichling and E. P. Goodrich.

The Secretary presented the following communication relative to the appointment of a special committee on underground piping in city streets.

"DETROIT, November 22d, 1906.

"TO THE AMERICAN SOCIETY OF CIVIL ENGINEERS,

"GENTLEMEN:

"We, the undersigned members of your Society, respectfully request that a special committee be appointed to consider the subject of underground piping in city streets, with a view to recommending standard street sections, following which, municipal engineers, elected for short terms only, could lay out new work, not only to meet present needs, but also to give convenient and economical access to sewer, water, and other pipes, as the city grows.

"We believe that the present custom of constantly tearing up expensive pavements to get at piping laid under them is on the increase rather than decrease, and might be largely avoided by the work of a special committee whose duty would be to recommend among other things:

"a. Arrangement of piping in new streets.

"b. Re-arrangement of piping in older streets when about to be paved.

"c. Subways or re-arrangement of piping in business streets to meet modern needs of sewer, water, gas, telephone, heat, pneumatic tube, areas, etc., etc.

"Such a report would, by furnishing a standard, enable engineers to get the approval of Councils, and Boards, and Legislatures, to more up-to-date plans than would now be considered.

"This subject we consider one peculiarly adapted for the consideration of the Society, because municipal engineers have been too subject to political caprice to have been able to work out the problem of economically arranging the modern piping and modern pavements of city streets.

"Respectfully submitted,

"Rutger B. Green
Clarence W. Hubbell
Benjamin Douglas
Alex Dow
R. H. McCormick
Geo. H. Fenkell
E. E. Haskell
C. L. Crandall
E. J. McCaustland
I. P. Church
Clyde Potts
R. F. Proctor
R. B. Williams, Jr.
Henry C. Allen
W. B. Cogswell
Gardner S. Williams."

It was moved that the matter be referred to the Board of Direction (Art. VI, Sec. 12, of the Constitution).

The motion, being duly seconded, was adopted by a vote of forty-three Corporate Members.

Ballots for membership were canvassed, and the following candidates elected:

As Members.

Charles Phillip Bower, Philadelphia, Pa.
Marvin Chase, Wenatchee, Wash.
William Henry Code, Hollywood, Cal.
James Dearing Fauntleroy, Lynch Station, Va.
John Lyell Harper, Niagara Falls, N. Y.
Hans Ludwig Heldt, Sombrerete, Zacatecas, Mexico.
Henry Jervey, Mobile, Ala.
Maurice Edwin Kernot, Melbourne, Victoria, Australia.
Richard Bird Ketchum, Helper, Utah.
Elwood Norman Layfield, Chicago, Ill.
Marcus Winfield Lewis, Superior, Wis.
Manuel Marroquin y Rivera, City of Mexico, Mexico.
Guillermo Beltran y Puga, City of Mexico, Mexico.
Hiram Joseph Slifer, New York City.
William Gavin Taylor, Waterbury, Conn.
George Weston, Chicago, Ill.

As Associate Members.

William Townsend Anderson, New York City.
Edward Franklin Atwood, Boston, Mass.
Daniel William Bliem, East Berlin, Conn.
Norman Freed Brown, Pittsburg, Pa.
Edward Beauford Cauthorn, Columbia, Mo.
George James Schilling Collins, Omaha, Nebr.
Henry Stratford Devlin, New York City.
William Henry Dorsey, Baltimore, Md.
Arthur Cassidy Everham, Detroit, Mich.
Joseph Firth, Philadelphia, Pa.
Clinton Hinckley Fisk, New Orleans, La.
Murray Forbes, Greensburg, Pa.
Frank George Fowler, Mount Kisco, N. Y.
Walter Nettleton Frickstad, Berkeley, Cal.
Eric Hjalmar Frisell, City of Mexico, Mexico.
Alfred Cookman Gregory, Trenton, N. J.
Albert Valdemar Gude, Jr., Atlanta, Ga.
Walter Scott Hanna, Harrisburg, Pa.
Guy Walter Harris, Canyon, Tex.
Carl Hiram Holley, Visalia, Cal.
Wilhelm Jens Christian Howalt, Ridgway, Pa.
Harry Ludwig Maier, Wilmington, Del.
Charles Michael Morssen, New York City.
Cornelius Joseph O'Connor, New York City.
Marshall Barker Palmer, Rome, N. Y.
Frederick Atwood Pease, Cleveland, Ohio.
Alvin Cyrus Pflueger, New York City.
Charles Arthur Poole, Albany, N. Y.
Alfred Clare Reed, Mayari, Cuba.
William Belden Reed, Jr., White Plains, N. Y.
Charles Gordon Reel, Kingston, N. Y.
Phillip Jacob Reich, Toledo, Ohio.
John Francis Richardson, Grants Pass, Ore.
Malcolm Asher Rue, New York City.
Joseph Carl Schaeffler, Boston, Mass.
John Martin Schreiber, Newark, N. J.
Frederick Celestine Schubert, Celilo, Ore.
Layton Fontaine Smith, Baltimore, Md.
William Thomas Clare Spiker, Roanoke Rapids, N. C.
Grandison Gridley Underhill, Albany, N. Y.
Henry William Vehrenkamp, Cincinnati, Ohio.
Johannes Cornelis Vliegenthart, Tientsin, China.
Michael Wassner, Corry, Pa.
William Hammond Waugh, Greenville, Pa.

Howard Shay Williams, Buffalo, N. Y.
Christopher Stanton Wolcott, Brooklyn, N. Y.
George Wood, New York City.
John Stephen Worley, Toledo, Ohio.

As Associates.

Cameron C. Smith, Pittsburg, Pa.
Edward Percival Thompson, Manila, Philippine Islands.

The Secretary announced:

The transfer of the following candidates by the Board of Direction on June 4th, 1907:

From Associate Member to Member.

Bryan Cheves Collier, New York City.
Robert Ladd Gifford, Chicago, Ill.
Arthur Stanley Hobby, Havana, Cuba.
Frank Forrest Sinks, Chicago, Ill.

The election of the following candidates:

As Juniors.

On April 2d, 1907:

James Lafayette Parker, New York City.

On April 30th, 1907:

Michael Smith Harvey, Ruby, Miss.
William Vincent McMenimen, New York City.
Forrest Leigh Smith, Perth Amboy, N. J.

On June 4th, 1907:

Frederic Burroughs, Aspinwall, Pa.
James Kip Finch, Easton, Pa.
Harry Minott Goodman, Berkeley, Cal.
Frederick Nathaniel Hatch, Ely, Nev.
Ralph Daniel Hayes, Goshen, N. Y.
Frederic Learoyd Humphrey, Selden Station, N. Mex.
Fritz Miller, Nampa, Idaho.
Henry Lanark Miller, Santa Fé, Argentine Republic.

The Secretary announced the following deaths:

Sir Benjamin Baker, elected Honorary Member May 5th, 1897; died May 19th, 1907.

Calvin Easton Brodhead, elected Member February 21st, 1872; died April 29th, 1907.

DANIEL FARRAND HENRY, elected Member July 7th, 1875; died May 13th, 1907.

MERRITT HARRISON ROGERS, elected Member January 2d, 1890; died May 3d, 1907.

Adjourned.

ELECTIONS TO MEMBERSHIP.

The following candidates were elected on ballot canvassed July 10th, 1907:

AS MEMBERS.

JOHN ALLEN BEELER, Denver, Colo.
WALDO CLAYTON BRIGGS, New York City.
WALTER WILSON CROSBY, Baltimore, Md.
HERBERT CHAPIN DAGGETT, Boston, Mass.
JOHN BAGLEY DIMMICK, Pittsburg, Pa.
EDWIN GEORGE EVANS, Hampton, N. B., Canada.
JOHN LINCOLN HALL, New York City.
JOHN WILSON HAMILTON, New York City.
ROBERT FRANCIS HAYWARD, Mexico, D. F., Mexico.
SAMUEL HAMILTON HEDGES, Seattle, Wash.
ERNEST ROWLAND HILL, New York City.
ERNEST GEORGE HOPSON, Portland, Ore.
ARTHUR LEWIS JONES, Ogden, Utah.
SAMUEL LIPPINCOTT GRISWOLD KNOX, Milwaukee, Wis.
BALIE PEYTON LEGARÉ, San Francisco, Cal.
HENRY MARTYN MACKAY, Montreal, Que., Canada.
PETER MOGENSON, Spokane, Wash.
JOHN EDWARD SCHWITZER, Winnipeg, Man., Canada.
JOHN MAXWELL SHERRERD, Easton, Pa.
THOMAS CULLEN BRYANT SNELL, Lynchburg, Va.
WARREN POWELL WOOD, Lewiston, Idaho.

AS ASSOCIATE MEMBERS.

WILLIAM GREENE ATWOOD, Cleveland, Ohio.
JOHN VANDERVEER BEEKMAN, JR., Boston, Mass.
NEWTON DAVIS BENSON, Providence, R. I.
JOHN HENRY BOWDITCH, New Brighton, N. Y.
ORRIN LAWRENCE BRODIE, New York City.
CLARENCE EDSON CARPENTER, Yonkers, N. Y.
WILLIAM DEXTER CLARKE, Milford, Cal.
LOREN BRADLEY CURTIS, Denver, Colo.
ERNEST FRANKLIN DEACON, Altapass, N. C.
BRENT SKINNER DRANE, Carlsbad, N. Mex.
ROBERT WILLSON FENN, Panama, Panama.

Paul Evans Green, Chicago, Ill.
Gustaf Edward Gustafson, Chicago, Ill.
John Lawrence Hyde, Westfield, Mass.
Ernest Lee Jahncke, New Orleans, La.
Vernet Albert Kauffman, Nueva Casas Grandes, Chihuahua, Mexico.
Forest Henry Lancashire, Monterey, Mexico.
William Caswell Smith Lemen, Brunswick, Ga.
Drew Jones Linard, McCall Ferry, Pa.
Paul McGeehan, Boone, Iowa.
Royal John Mansfield, Manila, Philippine Islands.
Charles Maynard Mapes, New York City.
Thomas Herbert Means, Fallon, Nev.
George Emil John Pistor, East Orange, N. J.
Walter Frederick Reichardt, Little Rock, Ark.
Franklin Henry Robbins, Pittsburg, Pa.
Herbert Fulwiler Robinson, Santa Fé, N. Mex.
Norman Salisbury Sprague, Pittsburg, Pa.
Charles Underhill Stepath, New York City.
Stuart Augustus Stephenson, Jr., Caguas, Porto Rico.
Charles August Thanheiser, Houston, Tex.
Charles Clarence Ward, Corbett, Wyo.
Joseph Weidel, Trinidad, Colo.
Thad Loren Wilson, New York City.

As Associates.

Charles Henry Eglee, Boston, Mass.
James Joseph Ferris, Jersey City, N. J.
Hermann Von Schrenk, St. Louis, Mo.

THIRTY-NINTH ANNUAL CONVENTION HELD IN MEXICO CITY, MEXICO, JULY 8th-10th, 1907.

PRELIMINARY MEETING.

Monday, July 8th, 1907, 8.30 P. M.—A preliminary meeting was held at the "Mineria," in the City of Mexico, Sr. Leandro Fernandez presiding. Sr. J. Ramón Ibarrola, representing the Mexican Society of Engineers and Architects, delivered an address of welcome to the Society.

Onward Bates, Vice-President, Am. Soc. C. E., responded in behalf of the Society.

Hon. Leandro Fernandez, Minister of Public Works of Mexico, and President of the Mexican Society of Engineers and Architects, then, in the name of the association, declared the Thirty-ninth Convention of the American Society of Civil Engineers formally inaugurated.

BUSINESS MEETING.

First Session of the Convention, Tuesday, July 9th, 1907.—The meeting was called to order at 8.30 P. M.; Vice-President Onward Bates in the chair; Charles Warren Hunt, Secretary; and present, also, about 60 members and a number of guests.

The Secretary presented a report giving the result of the suggestions of members as to the time and place for holding the Annual Convention of 1908.*

The subject was discussed, and on motion, duly seconded, was referred to the Board of Direction with power.

The Secretary presented a report relating to the vacancy on the Nominating Committee due to the death of the late Charles Davis, M. Am. Soc. C. E., stating that he had been instructed by the Board of Direction to call the attention of the Business Meeting of the Annual Convention to this fact.

On motion, duly seconded, it was resolved that no action be taken.

A report from the Special Committee on Rail Sections was presented by the Secretary.†

The report was not discussed, and on motion, duly seconded, was ordered printed in *Proceedings*, the whole matter being left open for discussion by the membership of the Society, and the report made an order of business for the next Annual Meeting.

Adjourned.

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*See page 279.

†See page 290.

Second Session, Wednesday, July 10th, 1907.—The meeting was called to order at 10 A. M.; Vice-President Onward Bates in the chair; Charles Warren Hunt, Secretary; and present, also, about 125 members and guests.

The Secretary presented the Annual Address of President George H. Benzenberg, entitled "The Engineer as a Professional Man."*

The first topic for discussion was then taken up, the topic being the following:

"Is it a better policy to purchase and control water-sheds, thereby preventing the pollution of impounding reservoir supplies, or to suffer a certain amount of pollution of such supplies, relying upon filtration to correct the effects thereof?"

The opening discussion on this subject, by George W. Fuller, M. Am. Soc. C. E., was then read, as was also a written communication from George A. Soper, M. Am. Soc. C. E. Discussions on this subject, by Messrs. F. Herbert Snow, D. D. Clarke, Pablo Solis and Octavio Guzmán, were presented by title, and the subject was further discussed orally by Messrs. M. Marroquin, M. R. Sherrerd, Gardner S. Williams, J. T. Noble Anderson, William B. Fuller, J. Waldo Smith, F. W. Blackford, S. Bent Russell, William J. Baldwin, and Charles B. Ball.

The second topic for discussion was then taken up, the topic being the following:

"(*a*) What is the best system of construction for foundations of heavy structures on ground such as that of the City of Mexico, which is an alluvial deposit about 300 ft. in depth, and similar in character to that at New Orleans?"

"(*b*) Will iron or steel used in foundations, independently or in combination with other materials, last indefinitely when in direct or indirect contact with water?"

"(*c*) Will the strength and durability of concrete in foundations be affected if before setting there is : (1) an excess of water; (2) lack of compression; (3) too rapid desiccation?"

The Secretary read the opening discussion by John F. O'Rourke, M. Am. Soc. C. E. Mr. Marroquin then presented in English an abstract of a paper on this subject prepared by Mr. Gilberto Monteil, and also spoke upon the subject personally, and the topic was further discussed by Messrs. Lansing H. Beach, Miguel Rebolledo, Henry W. Hodge, G. E. P. Smith, and F. G. Jonah, and the Secretary presented by title written discussions by Messrs. J. C. Meem, M. Morssen, J. A. L. Waddell, Pablo Solis and Octavio Guzmán.

Adjourned.

* *Transactions*, Am. Soc. C. E., Vol. LVIII, p. 515.

Third Session, Wednesday, July 10th, 1907.—The meeting was called to order at 3 P. M.; Vice-President Onward Bates in the chair; Charles Warren Hunt, Secretary; and present, also, about 100 members and guests.

The following topic was discussed:

"Will the paving materials of the present be used in the construction of the pavements of the future?"

The Secretary presented the opening discussion, prepared by George W. Tillson, M. Am. Soc. C. E., and the subject was discussed by Messrs. Horace Andrews, Lansing H. Beach, N. P. Lewis, E. M. T. Ryder, and G. S. Williams, and the Secretary presented written communications on the subject from Messrs. J. H. Haylow, P. W. Henry, Clifford Richardson, and W. H. Lawton.

The fourth topic was then taken up for discussion, the topic being as follows:

"(*a*) What are the factors which determine the maximum economical grade for electric railways?"

"(*b*) In establishing direct lines with heavy grades, under what conditions will it be found practicable to use electric locomotives and gas-engine generating stations, rather than traction by steam locomotives?"

The Secretary presented the opening discussion on this subject, prepared by George Gibbs, M. Am. Soc. C. E. The subject was discussed orally by Messrs. R. H. Hayward, W. W. Follett, J. T. Noble Anderson, and T. A. Corry.

Adjourned.

Fourth Session, Wednesday, July 10th, 1907.—The meeting was called to order at 8 P. M.; Vice-President Onward Bates in the chair; Charles Warren Hunt, Secretary; and present, also, 75 members and guests.

The following topic was taken up for discussion:

"(*a*) What is the best apparatus and most economical system for cleaning producer or furnace gas, to be used in gas engines?"

"(*b*) To what extent is ordinary producer gas, made from bituminous coal, used in gas engines, and what practical results have been obtained by any methods for removing tar or soot?"

The Secretary presented the opening discussion, prepared by James Christie, M. Am. Soc. C. E., and by title written communications on the subject from Messrs. Robert H. Fernald and Tomilion Geelen, and the subject was discussed by Messrs. Buchanan and J. Waldo Smith.

On motion, duly seconded, the chairman was authorized to appoint a committee to draft suitable resolutions expressing the thanks of the Society and its appreciation of the hospitality extended to the party in Mexico.

On motion, duly seconded, it was moved that the courtesies of the House of the American Society of Civil Engineers be extended to the Mexican Association of Engineers and Architects, and to the Mexican Association of Military Engineers, both of the above motions being carried unanimously.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

June 4th, 1907.—Past-President Stearns in the chair; Chas. Warren Hunt, Secretary; and present also Messrs. Bowman, Gibbs, Hazen, Hodgdon, Noble, Sherrerd and Tillson.

A payment of $10 000 on the principal of the mortgage on the Society House was authorized to be paid July 1st, 1907.

The following Special Committee was appointed to report on the status of Engineering Education in this country, and to recommend measures calculated to place it on the highest plane of efficiency:

DESMOND FITZGERALD, *Chairman;*
BENJAMIN M. HARROD, D. W. MEAD,
ONWARD BATES, CHARLES HANSEL.

Applications were considered, and other routine business transacted.

Tuesday, July 9th, 1907.—The Board met, in accordance with the Constitution, during the Thirty-ninth Annual Convention, Onward Bates, Vice-President, in the chair; Charles Warren Hunt, Secretary; and present, also, Messrs. Bowman, Sherrerd and Smith.

No quorum being present, the Board then adjourned.

REPORT IN FULL OF THE PRELIMINARY SESSION OF THE THIRTY-NINTH ANNUAL CONVENTION, AND OF THE BUSINESS MEETING, HELD IN THE "MINERIA," IN THE CITY OF MEXICO.

PRELIMINARY MEETING.

Monday, July 8th, 1907, 8.30 P. M.

The meeting was called to order at 8.30 P. M. in one of the halls of the "Mineria," in the City of Mexico, by Hon. Leandro Fernandez, Minister of Public Works, and President of the Mexican Society of Engineers and Architects, when the following programme was carried out.*

Address of Welcome by Sr. J. Ramón Ibarrola, C. E., as Representative of the Mexican Society of Engineers and Architects.

Address of Welcome.

SR. J. RAMÓN IBARROLA.—Gentlemen of the American Society of Civil Engineers, and Ladies: Acting on a proposal of our honored President, who in such a worthy manner fills the prominent position of Secretary of Communications and Public Works in the Cabinet of the President of the Republic, who has bestowed upon me the undeserved distinction of tendering the American Society of Civil Engineers a hearty welcome on the occasion of their visit to this our capital city, where their thirty-ninth convention is to be held; I feel under great obligations for the honor that befalls me. I recognize that I owe it not to any merit on my part, but simply to the fact of my being one of the oldest members of our profession in the Republic, one of the founders of our association, and one who, having resided in the United States at many different times, has become familiar with the wonderful works of that most wonderful country, where he has been honored by the friendship of such men as Alexander Holley, Eckley B. Coxe, Professor Morton, John Fritz, and so many more who enjoy a world-wide reputation, and to whose kindness he owes the most flattering distinctions. At the same time, I must acknowledge my utter inability to express in a worthy manner the feelings of my brother engineers on this solemn occasion, when we see among us in this time-honored historical hall so many brilliant representatives of the noble profession of engineering in its multifarious branches. It is certainly a great treat to have you American engineers sitting side by side with us at this gathering, of which nobody dreamed in not a very distant past, and that has become possible, easy, and pleasant, thanks to the steel ribbons that bind together your northernmost

*Several musical selections, by an orchestra furnished through the courtesy of the Hon. Leandro Fernandez, were given during the session.

Address of Welcome (continued).

cities, nay, the cities of Canada, with our principal cities and the banks of the Rio Bravo, along our Central Plateau, down to the Gulf of Mexico, the Pacific Ocean and our southern frontier. Our intercourse during the days you are to spend here will be very pleasant and useful to you, our distinguished guests, and to us, your cordial hosts, since you bring us the ripe fruits of a science gathered in your technical schools, and in your universities, and in the experience acquired in so many works that most deservedly astonish the world by the greatness of their conception and the wonderful methods and appliances used in their execution.

In dealing with the topics selected for general discussion at this convention, we expect to offer you an excursion to the new water-works, designed and now under construction for the supply of the City of Mexico, and, as the engineer who is the author of these works, and is their actual director, will be with us, he will lay before you the thorough and exhaustive surveys and studies that preceded and determined the adoption of the plans, the execution of which has been entrusted to his recognized ability. You will, in return, give us your sincere opinion on the same, and tell us something about the colossal work undertaken in your country for the water supply of Greater New York. In that way, while you will be enabled to judge by your own inspection of what our engineers can do and the way in which they do it, we, on our part, will avail ourselves of your advice and your experience, turning them to great profit.

It will be a great honor for me, as Director of the Hydrographic Commission of the Republic, to invite you to an excursion to the Drainage Works of the Valley of Mexico, and to give you on the very ground on which they are located a cursory description of the topography and the hydrography of that most interesting basin. Your attention will thus be drawn to the wonderful work of the Aztec Emperors, long before the Spanish conquest, to those executed by the Spaniards in the Colonial period of our history, and finally to the grand work undertaken and executed by the firm, wise, and far-sighted administration of our actual President, a work that constitutes one of his greatest and purest glories, and the completion of which we all hope he will live long enough to witness, and which will solve in a definite way the complex problems of drainage of the Valley of Mexico and the proper disposal of the waters that flow into it from the lofty mountains by which it is surrounded and entirely enclosed. This afforded the possibilities of undertaking the proper sanitation of the City of Mexico, carried out according to the plans of one of our most brilliant engineers, and whom you count among the members of your society.

The operations required for the drainage of the valley and those

executed for the construction of the sewers in the city have produced deep alterations in the statical conditions of its soil, and these have made themselves felt mostly by the sinking of old buildings, and of some more recently built, and a variation of the levels in several points of the valley. This fact has led to very interesting investigations about the proper kind of foundations to be adopted in our city, and a good many exhaustive researches and practical experiences have been made by several of our engineers, mostly by the distinguished Under-Secretary of Communications and Public Works, whose modesty has deprived the scientific world of the valuable results of his long and scrupulous labors.

As the question of foundations will be one of the topics dealt with in our sessions, I expect our engineers will lay before our American friends the facts relating to such interesting problems that the discussions about them cannot fail to be exceedingly important, since there are so many delicate points underlying the same, on account of the drainage of the City of Mexico and the surrounding country, owing to the sewers established in the former and to the flow of the water from the soil toward the main outlet of the valley.

Another question submitted to your convention has acquired a great importance; it is that relating to pavements. I have no doubt that the Direction of Public Works, having under its control works of a municipal character, will give us the most interesting data on this subject.

In dealing with these and the other questions that may arise in the course of our discussion, your advice, brother engineers from the North, will be for us a most valuable contribution. You come from a country where every day a new scheme surprises the world by the boldness and novelty of its features. Whatever you dream at night you turn into a reality the next morning. You have raised to the region of the clouds those wonderful buildings, some of them real architectural marvels, cut in marble and granite, and masterpieces of engineering skill and design, and the construction of their steel frames that insure perfect stability. You have carried their foundations by the most approved methods through thick layers of quicksand and clay down to rock bottom, and not satisfied with making them twenty stories high you undertake the construction of new ones that will have over forty stories. Where are you going to stop? There seems to be nothing in Nature to check your activity and your enterprise. You conquer every obstacle. You have built across your mighty rivers those wonderful bridges on the spans of which you have provided tracks for electric cars, wagon roads and walks for passengers on foot. Well, that seemed to be enough, yet you didn't think so, and not satisfied with your Brook-

Address of Welcome (continued).

lyn bridge and with the new suspension bridge, you determined to cross the rivers by means of tunnels located far below the level of their deep bottom, and you have succeeded, and they are there, your great tunnels, having your Imperial City as their center. I would never end if I were to mention the many wonders of your country in the vast field of engineering, yet I cannot stop without saying a word about the admirable institutions in which you train your engineers. I was fortunate enough to visit your special schools, your universities; I examined all their departments; I witnessed the work in their shops, in their laboratories; I attended their lectures, and I did not wonder any more at the splendid results of education and the instruction imparted in those centers of learning where, moreover, the visitor, if he be a foreigner, is always sure to be received with the utmost courtesy and given all the facilities to familiarize himself with the methods adopted. I cannot forget how I was received in the Universities of Pennsylvania, Lehigh, Columbia, Yale, Harvard, and Cornell, and in Stevens Institute, where many years ago I used to spend delightful hours in the company of Professor Morton; in the far-famed Boston Technical School; in old Rensselaer, and in many other places devoted to the teaching of those sciences without which no engineering education is complete. From this venerable hall which for a hundred years has been the meeting place of many illustrious men, from this sacred precinct, sacred to me with memories of past generations, I send my heartfelt thanks to those men who in those places received me and befriended and overwhelmed me with the most flattering and undeserved distinctions.

And now, my friends, after such a review of the great things of your glorious country, what can I show you in return? Well, I think I can say a few words for this country, whose citizens are glad to have you in their midst, and in saying that I do not fear to be blinded either by personal or national vanity, since I have reached that age at which men and things are seen as they really are, and appraised at their sterling worth. When the fire of our eyes is extinguished, but, instead of it, there is light; when, knowing that we are nearing our end, we do not any more live for ourselves, but for those who come after, applying to them and to us with great propriety the words of the Baptist, *"Oportet illium crescere, me autem minui,"* "It is proper for him to grow, for me to lessen."

Referring to things I would recommend you to examine while you are here, are some of the old buildings of which my friend, Mr. Morison, used to speak with such genuine enthusiasm in our

after-dinner conversations in Chicago ten years ago. He described them both with the accuracy of a man well posted in the sciences of construction, and with the *"amore"* of an artist whose soul had been enraptured by their beauty, and he often told the distinguished friends who had been sitting with us at the table that if the United States were the country of iron and steel constructors, well could Mexico boast of being the country of fine masonry work, showing plainly its Latin origin. I think that what Mr. Morison admired might be well worthy of your attention, and—pray mind it—I am not giving you my own opinion of our buildings, but I simply quote that which was expressed by one of your greatest and most highly respected engineers.

Passing to another kind of works, it would be worth while to study those built by the Spaniards for the water supply of the City of Mexico and some other cities; the former, at least, in what refers to old masonry aqueducts, do not exist any more, but when you were coming here your train passed under the lofty arches of Queretaro Aqueduct, built by Marquis de Villar del Aquila, a great benefactor of that city. Several others of the same kind might be cited, among them the Aqueduct of Cempoala and that of Las Remedios, not very far from the track of the National Railway.

Referring to works for irrigation, I might say we have some very remarkable ones which are almost unknown even to our people, and yet well worthy of attention by their proportions and by the clever way in which they were executed. There is among the excursions tendered you along the Mexican Railway, if you had time to stop at every point of it, you might admire the wagon roads, built in the colonial period, between Mexico and Vera Cruz, which are fine specimens of engineering ingenuity, and similar to them were the high roads, called "Royal Roads," leading north toward the principal cities of the country and west toward our seaports on the Pacific Ocean.

About our actual doings you may judge for yourselves; we will show them to you and give you all sorts of facilities for examining them. There are, within easy reach, the new water-works for our city, and their able director, by whom the original idea of utilizing for such purpose the springs of Xochimilco was first started, and by whom all the designs required for the execution of the work have been made, and who has given to it such splendid organization, is here at hand ready to answer any questions you may ask. He will supply you with an interesting pamphlet on the drainage of the City of Mexico and its sewerage. This great work was designed, as I have already told you, by one of our engineers, a member of your society, belonging also to our association, and whose well-

Address of Welcome (continued).

earned fame will survive him as long as the beneficial effects of his work are felt. You may depend upon him for any information you may require about his work.

Now, I could never finish if I were to mention all the new and great works carried out during the administration of General Diaz. He has been the creator of our railroad system. Under his rule, the Tehuantepec Railroad and its two great harbors have been executed, and this bridge of the world's trade is showing, even now, when it has just been opened, some of its future grandeur. Our Light-house Department has been created, and the illumination of our coast, on the Pacific, on the Gulf, and on the Caribbean Sea is nearly completed. New buildings, which would do honor to any country, like the new post office, the Palace for the Legislative Power, and for the Department of Communications and Public Works, have been erected or are in course of erection and pretty well advanced. There has not been, in the past thirty years, any international exhibition, be it in Europe or in the United States, where Mexico was not properly represented. And so it has been at the several Scientific Congresses held in the great capitals of the old and the new world. Our school system has received a powerful impulse, and the attendance of the classes is very striking. Our higher educational institutes are kept on the most liberal principles, and are also amply patronized. Mexico, in one word, has been doing wonderful work in a quiet way, without any puffing, doing it as the German poet says, *"Ohne Hast, ohne Rast, wie die Sterne."*

You are dealing at present in your country with some vital and most delicate questions, relating to the working of your railroads. Most intricate discussions have taken place between the National Government and the several companies, and nothing up to this time has been definitely settled. Here we do not experience such trouble, and we can never have it, thanks to the foresight of our executive and to the way in which concessions for railroads have been granted, putting them all exclusively under Federal Control and establishing on a well-defined basis the supreme authority of the National Government in all matters relating to the construction and the operation of the lines. Moreover, the great financial operations carried out recently so successfully by our Secretary of the Treasury, by means of which the National Government has acquired a controlling interest in our principal railroads, has solved beforehand a good many future difficulties, and has put in his hands this most powerful agent of modern, social and political life.

So it has been, to a certain extent, with the policy relating to our waters; concessions have been granted by the Department of Fomento for the utilization of our streams, and the result has been the erection of enormous power plants like those in the neighbor-

hood of Orizaba, in the State of Vera Cruz; the Portezuelo and Metepec, near Atlixco, Puebla; the Guanajuato Water and Electric Company, utilizing the waters of the River Duero, in the State of Michoacan, and herewith infusing new life into the legendary City of Guanajuato; and the colossal works of Necaxa, which you are invited to visit.

Some doubts were expressed not very long ago about the right of the Federal Executive to legislate on the question of water applied to irrigation, but now nobody would dare to take action after seeing the wonderful results brought about in the cotton region of the States of Durango and Coahuila—called the "Laguna"—by the regulations established by the National Government for the distribution of the waters of the River Nazas. A tract of land, sold fifty years ago for less than $80 000, could not be bought now for a hundred millions. New and powerful industries and new towns have sprung up in that region, where at present prosperity reigns supreme.

You will see during your stay here how safe our cities are, how life and property are protected all over our territory, and how absurd, not to say criminal, are those slanderous reports of plots started by our people against foreigners. The only foreigners in Mexico are bad men, and those we do not allow in our midst, whether they may have been born in Mexico or elsewhere. You will very likely be enabled on your return home to tell your friends that you met our President, God bless him, a President who goes wherever he likes by day or night, on foot, on horseback, or in his carriage, all alone, without ever having any guard or any escort or any policeman around him, not even when he goes to the mountains to indulge in his favorite sport, hunting, and when he stays for a week or two camping out, allowing everybody to admire his wonderful vigor and activity. As long as you are here try and do away with any prejudice you might have. Live our life as you breathe our air; get into our society, and you will see how kind and warm-hearted it is toward men of good will, and when you go back to your family and friends tell them what Mexicans really are, and how they practice hospitality.

Gentlemen of the American Society of Civil Engineers, since you honor us with your presence in this city, let me tell you that here when we meet a friend we do not confine ourselves to the somewhat cold and ceremonious handshaking of your country. We open our arms and press that friend against our breast so as to let him feel the beating of our heart. If you were to embrace the members of our profession gathered here to meet you, you would know by your own experience the warmth of their feelings and the sincerity of the welcome they tender you. May your short stay in this country be pleasant to you, and let us hope that our meeting may be fruit-

Address of Welcome (continued).

ful and contribute to tighten the bonds of cordial and everlasting friendship, not only between individuals, but also between the United States and Mexico. And now I will say again, gentlemen, be welcome to this country, and God bless us all. (Applause.)

Reply to Address of Welcome.

ONWARD BATES, VICE-PRESIDENT, AM. SOC. C. E.—Mr. Chairman, ladies and gentlemen: Our President, Mr. Benzenberg, expected to be with us to-night, but at the last moment was unavoidably detained, and I wish to express regrets that he is not here; I am sure that I express the regrets of all our members who are here, and my own in particular, because Mr. Benzenberg could have answered what has been said better than I can. It is a difficult matter for me to express properly our thanks this evening, which is my present duty, because the words would seem to fail me. We are very much honored to have you preside at our reception; we know of your high personal character and of the eminent service that you render your government as its Minister, and our hearts have been touched by our professional brother, Sr. Ibarrola. I hardly know how to respond to such expressions of friendship and esteem as he has made to us.

There are not as many members of the American Society of Civil Engineers here to-night as had been expected. The condition of the prosecution of the public works in the United States is such that it is very difficult for our members to get away for the three weeks' time that it requires to visit the City of Mexico, and a good many who had promised found themselves in the condition of Mr. Benzenberg, and had to give up their hopes and stay at home; nevertheless, we are a representative body, and we fairly represent our Society, I think. When we are at home we often hear the statement made that when you visit a Mexican gentleman in his home he makes you a present of his house and all that it contains. Now, we can readily appreciate that ourselves since we have arrived here. From the time we crossed the border and the Government permitted the Custom House officers to pass our luggage without examination, everything has been ours.

We have, first, to thank the officials for this beautiful hall in this stately building, "Mineria." To-day we owned about 200 miles of fine electric railway system with its 250 cars, more or less, of the most approved pattern, and at noon we took possession of the Country Club, where we dined on dishes that were as delicious as they were novel to us. To-morrow we expect to have the water-works in our possession, and I suppose as we go on from day to day taking over these valuable properties that are tendered us we shall ultimately acquire all the Republic of Mexico, with the Gulf of Mexico thrown in. I hope that this will not turn our heads with self-esteem, but rather that it will turn our hearts toward our friends who are so kind to us.

Mr. Chairman, I can scarcely find words to express our thanks for the kindness and more than kindness and attention which we have already received; we will have to try and show it in our actions.

The civil engineer is a soldier of peace; he is ready to give his services and his life for the good of his fellow men; it is the civil engineer who provides for the wealth of the nations and the comfort of mankind. He is sometimes also a soldier at war, because, when his country needs him, no man is more willing to give his services and risks his life for his country than the civil engineer, but in being a soldier of peace there is great distinction. The civil engineer serves the whole world; he is not limited to nationality; he goes where he is needed, wherever he can do good, and we have a common brotherhood. The American Society of Civil Engineers is a National Society, has members in every civilized nation on the face of the earth, and all its members are entitled to go where they are needed, into any nation whatever, to do their work. We come down here on this convention trip and we meet our brother engineers of the Republic of Mexico. Some of them are members of the Society and we feel entirely at home with them, and I am sure that each one of us reciprocates the friendship that Sr. Ibarrola has expressed in his address of welcome to-night, and when this trip is over and we go to our homes we will have at least learned one good Mexican word—the word *Amigo*. (Applause.)

HON. LEANDRO FERNANDEZ.—In the name of the Association of Engineers and Architects of Mexico, I now declare the Thirty-ninth Annual Convention of the American Society of Civil Engineers formally inaugurated, and open for the transaction of business.

BUSINESS MEETING.

Tuesday, July 9th, 1907, 8.30 P. M.

Business Meeting called to order.

ONWARD BATES, VICE-PRES. AM. SOC. C. E.—Gentlemen of the American Society of Civil Engineers, I am calling you to order now for the first business meeting of the Society here. The first order of business is the report of the Secretary on the suggestions received from the membership as to the time and place for holding the next Annual Convention, and I ask the Secretary to read the report.

The Secretary read the following:

Convention of 1908.

Report of the Secretary in Answer to Circular of Inquiry Concerning the Time and Place for Holding the next Annual Convention.

"To the Thirty-ninth Annual Convention, Mexico City:

"In accordance with custom, and under instruction of the Board of Direction, the Secretary forwarded to each member of the Society on May 31st, 1907, a circular with return blank for suggestions

Convention of 1908 (continued).

as to the time and place for holding the next Annual Convention, and now reports the result of that circular.

"As to the place for holding the Convention.

"Total number of suggestions received, 520, as follows:

Denver, Colo.	394
Boston, Mass.	9
San Francisco, Cal.	9
New York City	7
Pittsburg, Pa.	6
Duluth, Minn.	5
New Orleans, La.	5
Seattle, Wash.	5
Panama	5

"The following places have received four votes each:

Chicago, Ill.
Kansas City, Mo.
Mackinaw Island.
Quebec, Canada.
Saratoga, N. Y.

"The following places have received three votes each:

Atlantic City, N. J.
Montreal, Canada.
St. Louis, Mo.
Washington, D. C.

"The following places have received two votes each:

Cape, May, N. J.
Cincinnati, Ohio.
Colorado Springs, Colo.
Niagara Falls, N. Y.
St. Paul, Minn.
Watch Hill, R. I.
White Mountains.
Somewhere in District No. 1.
Region of Great Lakes.

"The following places have received one vote each:

Baltimore, Md.
Buffalo, N. Y.
The Catskill Mountains.
Chattanooga, Tenn.
Detroit, Mich.
Galveston, Tex.
Havana, Cuba.
Lake George, N. Y.
Manhattan Beach, N. Y.
Manila, P. I.
Middle States.
Milwaukee, Wis.
Minneapolis, Minn.
Montgomery, Ala.
Northern Part of Michigan.
Nova Scotia.
Portland, Ore.
Paris, France.
Philadelphia, Pa.
Sault Ste. Marie, Canada.
Steamer on Great Lakes.
Toronto, Canada.
Utica, N. Y.
Victoria, B. C.
Virginia Hot Springs, Va.

"As to the time for holding the Convention, the opinions of members differ widely, as the following list will show. Many of the answers specify the exact date or some week in the month given, but they have been classed under each month wherever possible:

January	has	2	votes	July	has	139	votes
February	"	1	"	August	"	16	"
March	"	2	"	September	"	23	"
May	"	8	"	October	"	2	"
June	"	126	"	November	"	1	"

"It will be observed that the only months not voted for are April and December.

"The following votes can only be classified generally. They are as follows:

January or February	1	Any time it will suit the Denver Engineers	1
March or April	1	In Dry Season	2
April or May	1	Some Summer Month	23
May or June	2	Early Summer	1
June or July	23	Mid-summer	1
July or August	14	Early Fall	1
August or September	1	Early Autumn	1
April or October	1	Winter	1
May or October	1	One year from 1907 Convention	1
June or October	1	Any time most convenient	1
June, July or August	1		
July, August or October	1		

"The number of members voting who seem to have no preferences as to time is 120.

"Respectfully submitted,

"CHAS. WARREN HUNT,
"Secretary.

"NEW YORK, July 2d, 1907."

THE CHAIRMAN.—What action will you take on this report, gentlemen?

Moved that it be referred to the Board of Direction with power. Seconded.

THE CHAIRMAN.—It is customary, gentlemen, that the opinion of the members be expressed in discussion of such a motion. Is there any discussion?

GARDNER S. WILLIAMS, M. AM. SOC. C. E.—I would like to say just a word, as endeavoring to speak for perhaps the younger members of the Society. Those of us here are certainly hardly a representative body of the rank and file of the organization, and I think it is quite important that, in selecting a place for the convention, we should bear in mind those who cannot afford to spend the time that must be taken to come here this time. There are many of us who enjoyed the convention last year, which, I am free to say, was to me the most enjoyable one I had attended up to that time; nevertheless, it must be realized that there is a very considerable portion of our members who would not feel warranted in attending a convention at such a location, and these are the members the Board of Direction should consider. I therefore think it is proper that a portion of the time, at least, the wishes of those members who are not able to travel far, but who wish to attend these conventions, should be considered, and I trust that such a view will be duly considered by the Board of Direction.

THE CHAIRMAN.—Is there any further discussion? There seems

Discussion on Convention of 1908 (continued).

to be no further discussion. All in favor of the motion will signify by saying aye. Contrary, no. The motion is carried.

THE CHAIRMAN.—The next order of business relates to the vacancy on the Nominating Committee due to the death of the late Charles Davis. The Secretary will make a report on the subject.

Report of the Secretary on the Vacancy on the Nominating Committee.

Vacancy in Nominating Committee.

THE SECRETARY.—The Secretary respectfully reports that Charles Davis, M. Am. Soc. C. E., who was appointed a member of the Nominating Committee, January 16th, 1907, died February 21st, 1907, causing a vacancy in the Nominating Committee.

The Secretary reported the facts in the case to the Board of Direction, and on March 5th, 1907, the Board passed the following resolution:

"That no action be taken by the Board to fill the vacancy, but the Secretary is instructed to notify the Business Meeting of the next Annual Convention of the vacancy, in order that action may be taken by the Society."

It should perhaps be explained that there seems to be no provision in the Constitution for filling a vacancy in the Nominating Committee. The only duties of the Board of Direction in relation to the appointment of this committee stated in the Constitution, are that it "shall, from time to time, divide the territory occupied by the membership into seven geographical districts," for the purpose of this Committee, "shall announce such division to the Society on or before the first day of May in each year, and may prescribe a mode of procedure for appointing this Committee"; but, apparently, the only way in which the appointment can be made is by the Annual Meeting each year. I do not know that I have made the matter clear, but it is a fact that the Board of Direction did not know what to do with this vacancy, or any way in which it could act.

MR. WILLIAMS.—Is it the view that this meeting can take any action?

THE SECRETARY.—It is not my view that it can, but the Board of Direction has directed me to report the case to this meeting for such action as is deemed proper. I presume any action can originate in either one of the two general meetings of the Society, but it is not so specified in the Constitution.

H. C. KEITH, M. AM. SOC. C. E.—I was going to ask how many there are on the Nominating Committee. As I remember it, the number is large enough so that the absence of one, or the reduction of the number by one, would not be serious, as it seems as

though we might wait until the January meeting for electing a successor.

THE SECRETARY.—There are nineteen, altogether; seven geographical districts, two representatives from each district, making fourteen, and the five last living Past-Presidents.

I have a letter, in that connection, Mr. President, from a Member of the Society, which perhaps it would be well to read. It is dated June 18th and is from Robert A. Cummings, M. Am. Soc. C. E. I explained to Mr. Cummings, as I have explained to this meeting, and received this answer:

"TUESDAY, JUNE 18th, 1907.

"MR. CHAS. WARREN HUNT, *Secy.*,
"American Society of Civil Engineers,
"220 W. Fifty-seventh St., New York, N. Y.

"DEAR SIR:—I thank you for your letter of the seventeenth in reference to the vacancy caused by the death of the late Mr. Charles Davis, who was a member of the Nominating Committee of this district. I desire to propose the name of Mr. Geo. Barnsley as a member of the Nominating Committee from this district to take the place of Mr. Charles Davis, deceased. I would ask that his name be presented at the Convention for action.

"Yours truly,
"ROBT. A. CUMMINGS."

WILLIAM B. FULLER, M. AM. SOC. C. E.—You didn't say what district this was.

THE SECRETARY.—District No. 4.

MR. KEITH.—I move that it is the sense of this Convention that no action be taken.

Motion seconded by Mr. Williams.

THE CHAIRMAN.—Any discussion on this motion? All in favor of it will signify by saying aye. Contrary, no.

Motion carried.

Report of Committee on Rail Sections called for.

THE CHAIRMAN.—The next order of business will be the Report of the Special Committee on Rail Sections, and I ask the Secretary to make this report.

THE SECRETARY.—Mr. President: Since I left New York the following letters have been received.

"NEW YORK, July 1st, 1907.

"MR. CHAS. WARREN HUNT,
"Secr., Am. Society of Civil Engineers,
No. 220 West 57th Street, New York City.

"DEAR SIR:—I am sending you, herewith, copy of report of the Rail Committee, together with letter from Mr. Robert W. Hunt, Secretary of the Committee, which is self-explanatory in regard to the missing signatures.

"Yours respectfully,
"C. W. BUCHHOLZ,
"Consulting Engineer."

Discussion on receipt of Report of Committee on Rail Sections (continued).

"CHICAGO, June 24th, 1907.

"MR. R. MONTFORT, *Member, Rail Committee,*
"c/o Louisville & Nashville Ry. Co.,
"Louisville, Ky.

"DEAR SIR:—Enclosed you will please find the proposed report, which you will kindly sign and forward to Col. Prout, c/o Union Switch & Signal Co., Swissvale, Pa., with the request that he forward it after signing to Mr. Turner, whose address is 53 State St., Boston, Mass. You better give Mr. Prout Mr. Turner's address, as he may not know it, and I hope he will request Turner to forward it to Mr. Buchholz, c/o the Erie R. R. Co., New York, with the request that he send it to Secy. Hunt of the American Society.

"This will leave it short the signatures of Messrs. Carter and Roberts, but the latter is in Europe, and the former prefers not to sign the report, although he coincides with it; and as we are very anxious that Secretary Hunt should have it in time for the meeting of the Society in Mexico, it is important that the signatures should be rushed.

"Unfortunately, it was hung up from June 6th until a few days ago in Mr. Carter's office, owing to his absence on his line, and since that there have been one or two other delays, for which I assure you I have not been responsible.

"Asking you to kindly attend to this as promptly as you can, I remain,

"Yours truly,
"ROBERT W. HUNT,
"Secy., Special Rail Committee.

THE SECRETARY.—Before that Committee report is presented, it seems to be my duty to present certain facts, which are as follows: On January 17th, 1894, the Society, in Annual Meeting, adopted the following resolution:*

"*Resolved,* That reports of special committees upon engineering subjects shall be presented to the Secretary of the Society at least 30 days before their presentation to the Society at a business meeting, and shall be printed and sent out to the membership as soon thereafter as practicable, in the same manner as advance copies of papers are sent out, and with a proper cautionary notice that the report has not yet been presented to the Society, and is issued for the purpose of information and discussion only, with all rights of publication reserved."

The Board of Direction, on February 5th, 1907, instructed the Secretary to write to the Chairman of each of the Special Committees of the Society now in existence, calling attention to this resolution. The Secretary was further instructed to say that this rule would be enforced in the future in the matter of reports of Special Committees. All these facts were communicated to the Chairmen of the Special Committees on February 8th, 1907. This report, which has been received since our arrival in Mexico, cer-

* *Proceedings*, Am. Soc. C. E., Vol. XX, p. 17.

tainly does not comply with that resolution which the Board of Direction has said would be enforced.

THE CHAIRMAN.—We cannot receive this report unless we rescind the action of the Society; and I would ask what is your pleasure; shall it lie over until the next Annual Meeting in January, or do you wish to take some other action regarding it? It is competent for this meeting to revise that action of the Society if it desires to do so.

IRA O. BAKER, M. AM. SOC. C. E.—I think I understand what the Board of Direction meant by its construction of the rules concerning the publication of reports, and perhaps it is unfortunate. Possibly it could not be helped that this report is not now in print, but is that sufficient reason why it should not now be presented to the Society? I think there are certain discussions going on that make it desirable that this report should be heard. Would this meeting be reflecting upon the Board of Direction if we should receive this report and discuss it if it is so desired?

THE CHAIRMAN.—I think, Professor Baker, that acting on this now would reflect on the resolution of the Annual Meeting of the Society; it would be acting contrary to a rule that has been established, and I do not see how we can receive the report and consider it, unless we pass a resolution of the Society in this general meeting which will cancel the former action. We can do so, as I understand it, and then do what we please with the report.

A MEMBER.—Was the resolution of the Annual Meeting that the reports should be published or was it calling the attention of the Board of Direction to a former action? Will the Secretary state?

THE SECRETARY.—The original resolution, Mr. Chairman, was adopted by the Society in Annual Meeting on January 17th, 1894, and still remains on the books; it has not been cancelled. That is the highest authority we have in the Society.

A MEMBER.—Has it been lived up to always?

THE SECRETARY.—No, sir.

A MEMBER.—That is an important point on this occasion.

THE SECRETARY.—I think it is the fact that it has not been lived up to that caused the Board to take its action in notifying each of the committees that in future it would be lived up to.

A MEMBER.—But might it not be unfair to a committee of busy men to notify them, say, the first of March, that the Society was going to live up to a law that had been a dead letter for thirteen years? It seems to me that we are hardly treating our committee right to be so peremptory in reviving a dead law.

THE CHAIRMAN.—I think, in answer to that question, that it would be perfectly fair, and I doubt that we can admit that that is a dead law. There is a way which has been suggested by which we

Discussion on receipt of Report of Committee on Rail Sections (continued).

can act on this report, but unless that way is taken I should certainly rule that we cannot act without a new resolution to take the place of the one which now controls in the matter.

A MEMBER.—I move that the report be received as information and discussed accordingly.

MR. WILLIAMS.—I think this motion has not been seconded, and I would move that the resolution of the Annual Meeting of 1894 be reaffirmed by this meeting.

CHAS. B. BALL, M. AM. SOC. C. E.—I second the motion.

THE CHAIRMAN.—The motion is before us that the resolution referred to be reaffirmed, and it is open for discussion. Is there any discussion on this motion? I do not know that I am competent to rule on that, but it does not seem to me that the motion is in order, for if it is, and it is carried, the matter will be left just where it was, and if it is not carried it leaves the matter where it was.

A MEMBER.—I am not particularly interested in rail sections, but if there is any person here who is, I will just say a word or two. At a meeting of the American Railway Engineering and Maintenance of Way Association, at Atlantic City, they had a very interesting discussion with relation to rail sections, and it seems to me that the present is a proper time to hear something from the report of the American Society of Civil Engineers also; it seems to me a shame to delay this report for six months or a year, and I should like to see some way out of the difficulty, so that the matter in the report would get in print.

A MEMBER.—Is there a motion before the meeting?

THE CHAIRMAN.—The motion before the meeting is that the resolution referred to, requiring thirty days' notice of a report of a Special Committee and its printing and distribution among members, be reaffirmed.

A MEMBER.—It is my impression that the proper thing to do would be to move that that report be received and printed, as far as the proceedings of this meeting are concerned. If I understand the motion that was made several years ago and adopted, it was at least thirty days. By printing the report as a part of the proceedings of this meeting we give them six months instead of thirty days. I will not make a motion, as there is already one before the meeting, but it seems to me that that is what ought to be done.

MR. WILLIAMS.—It seems to me that there is a decided difference between printing the report in the proceedings of this meeting and printing it for distribution for the members, and I hardly think we ought to print that report and thereby take formal action of the Society until it has been sent out to members, and they have had an opportunity to read it. That is the very thing I wish to head off. This report should not become a part of the proceedings of the

Society until it has been submitted, in the preliminary manner provided, to the membership thereof, and for that reason I certainly hope that such a motion or action as has been suggested will not be taken at this time. The suggestion has been made that we might receive the report informally, have it read and discussed informally, and that no record of that discussion should appear upon the minutes, and that thereafter the report be printed for distribution. If such a method of procedure would meet with the approval of a considerable number here I would be glad to withdraw the motion I have made, but I would like to hear expression of opinion now upon it before doing so.

J. L. CAMPBELL, M. AM. SOC. C. E.—It appears to me that the suggestion made by Mr. Fuller and the gentleman who followed him is not a very good one. Possibly I didn't understand the reading of the resolution right; but, as I understand it, I see no reason why this report could not be read here in this meeting and, if the members desire, be discussed. That will not mean that the Society will have to take any decisive action in the way of accepting or rejecting the report at this time. It would have the effect, however, of presenting to us at the present time the conclusion of this Committee, and, as has been very truly said, this is an important subject, and any discussion of it is pertinent at the present time, and it does look too bad to have this whole thing laid over for twelve months without our knowing anything about what the Committee has recommended.

MR. KEITH.—This is a matter in which I am personally very much interested, although not directly connected with rail work, but when I think of the small number here at this Convention compared with the great number of those who are intensely interested in this subject and who are not present, it seems to me that it is hardly fair to the absent members of the Society that we should receive the report and have its first discussion here without giving them an opportunity. I think that the resolution that was passed thirteen years ago was a good one. I remember the intense excitement that existed at the time that resolution was passed, and it was because of a case somewhat like this, if I remember rightly, that it was passed. It seems to me that it is better that the matter should lay over until the regular time. I am very sorry that this is necessary, because I think that this is an opportune time for the presentation of such a report, but can we do it in fairness to those who are not present at this Convention? I think not.

MR. FULLER.—I would like to ask if, in the ordinary course of business, the Secretary would not send out this report now within, say, the next month. If that is the case it seems to me that it covers the point of getting the publication before the members.

Discussion on receipt of Report of Committee on Rail Sections (continued).

THE SECRETARY.—I cannot say that I would do it within the next month, because I may not be able to do it, but certainly within the next two months. I think perhaps it may throw some light on the subject to say that when this original resolution was passed we did not have the same system of publications that we have now. In 1894 we did not publish advance copies of papers in the form of *Proceedings,* hence all such reports had to be sent out in the form of advance copies. If this report were received at this meeting it would probably be published in the August number of *Proceedings,* and if this meeting were to take action, not necessarily a final action, in accepting or even in receiving it, and would pass a resolution that this report be brought up for action at the next Annual Meeting, it would seem that it might be advantageous to have it discussed here, and would not be in any way objectionable. The original resolution, as Mr. Keith very justly states, was passed because a report was brought in at the last minute, and this was objected to by members of the Society who had had no opportunity of seeing it before it was presented to the meeting, and who were therefore not prepared to take up the discussion. It seems to me with our present method, in which discussions on papers or reports of Committees are continued from month to month, that discussions on this report could be printed, and the whole matter taken up at the next general meeting.

MR. WILLIAMS.—I would like to move as a question of privilege that an invitation be extended to the members of the Mexican Society of Engineers and Architects to unite with the American Society of Civil Engineers in their meetings and join in the discussion.

THE SECRETARY.—I may say that that was done some two or three months ago.

MORRIS R. SHERRERD, M. AM. SOC. C. E.—I would move as a substitute to Professor Williams' motion, if it be entertained by the Chair, that the report of the Rail Committee be read and discussed, and printed in the *Proceedings,* provided that no action be taken on said report until the Annual Meeting.

MR. WILLIAMS.—I would be glad to accept that substitute if the seconder is agreeable.

MR. BALL.—That is agreeable to me, but while I am on my feet I would like to say that I recall exceedingly well the line of discussion referred to in 1894 when this matter was taken up; it was thought that, in justice to absent members, the report could not be received for discussion without having been previously printed, but this present occasion seems to justify an exception to that course, however, I feel sure that the action taken at that time should be sustained and should be enforced by the Board of Direction.

MANSFIELD MERRIMAN, M. AM. SOC. C. E.—Let us consider what was the purpose of this resolution. It was not to prevent the presentation of reports to the meetings of the Society, and their publication, but it was to prevent hasty and ill-advised discussion. As the rule has been repeatedly violated in the past, it seems that this Business Meeting would not go far wrong if it were to permit this report to be received and read, and to be printed and distributed as soon as possible. The subject of rail sections is one to which I have given some little attention, but I am sure I would not care to discuss the matter until I had carefully read the report of the Committee.

THE CHAIRMAN.—I would ask Mr. Williams to state the motion as he has accepted it, as it has been revised.

MR. WILLIAMS.—That substitute has been accepted by the mover of the original motion and by its seconder.

THE CHAIRMAN.—The original motion was that the former motion be reaffirmed.

MR. SHERRERD.—I offered a substitute which the mover of the original motion has accepted.

THE CHAIRMAN.—State it.

Resolution on Receipt of Report of Committee on Rail Sections.

MR. SHERRERD.—I moved that the report of the Committee on Rail Sections be read and be open for discussion, and printed in the *Proceedings,* provided no action thereon shall be taken until the next Annual Meeting.

THE SECRETARY.—If I might suggest, "and that it shall be made an order of business for the next Annual Meeting."

MR. SHERRERD.—Yes; that it shall be made an order of business.

THE CHAIRMAN.—That, gentlemen, is the motion which is before the meeting. Is there any discussion on it as you have heard it?

MR. KEITH.—It seems to me that in simply hearing a report on so important a matter as this, we cannot sufficiently adjust it to make the discussion all that would be desirable—that the first discussion of the subject should be—and therefore I would oppose it.

MR. SHERRERD.—My thought in suggesting that it be discussed is that, if any members of the Society who are here care to discuss any of its features, that discussion may go out with the report. Of course, any written discussion, either from those who are here or from those who may care to discuss it, can immediately be sent to the Secretary after the publication of *Proceedings,* and such discussion will, I believe, be printed before the Annual Meeting. Will they not, Mr. Secretary?

THE SECRETARY.—Yes.

MR. SHERRERD.—The discussions that may be received prior to the Annual Meeting will then be presented, and it will bring the whole subject before the Society in a shape in which the views of members can be ascertained by the membership at large.

THE CHAIRMAN.—Is there any further discussion on this, gentlemen? Then I will put the question. All those in favor of the motion will signify by saying aye. Contrary, no. The motion is carried.

The Secretary read the following report:

Progress Report of the Special Committee on Rail Sections.

Report of Committee on Rail Sections.

"GENTLEMEN:—Your Committee respectfully report that they have given the report, which they submitted under date of January 17th, 1906, and which was referred back to them, careful consideration, and would now report that they are in consultation with committees representing other societies and organizations, as well as other interested parties, on the subject of modified rail sections, with the purpose of preparing and submitting to your Society a new series of such sections.

"In this designing of heavier sections, particular attention is being given to the advisability of increasing the percentage of metal in the webs and flanges, as compared with the existing sections recommended by your Society.

"This they hope to accomplish in due time, and in the meantime respectfully submit to the Society for its consideration the following specifications for the manufacture of Bessemer and Open-Hearth rails:

"RECOMMENDED SPECIFICATIONS FOR BESSEMER STEEL RAILS.

"*Process of Manufacture.*—The entire process of manufacture and testing shall be in accordance with the best state of the art, and the following instructions shall be faithfully executed:

"Ingots shall be kept in a vertical position in the pit heating furnaces until ready to be rolled, or until the metal in the interior has had time to solidify.

"No bled ingots shall be used.

"There shall be sheared from the end of the blooms formed from the top of the ingots not less than twenty-five per cent., and if, from any cause, the steel does not then appear to be solid, the shearing shall continue until it does. If, by the use of any improvements in the process of making ingots, the defect known as piping shall be prevented, the above shearing requirements may be modified.

"The number of passes and speed of train shall be so regulated that on leaving the rolls at the final pass, the temperature of the rail will not exceed that which requires a shrinkage allowance at the hot saws, for a 33-ft. rail of 100-lb. section, of $6\frac{7}{16}$ in., and $\frac{1}{16}$ in. less for each 5-lb. decrease of section. These allowances to be decreased at the rate of $\frac{1}{10}$ in. for each second of time elapsed between the rail leaving the finishing rolls and being sawn. No artificial means of cooling the steel shall be used after the rails leave the rolls, nor

shall they be held before sawing for the purpose of reducing their temperature.

"*Chemical Composition.*—Rails of the various weights per yard specified below shall conform to the following limits in chemical composition:

	70 to 79 lb. Percentage.	80 to 89 lb. Percentage.	90 to 100 lb. Percentage.
Carbon	0.50 to 0.60	0.53 to 0.63	0.55 to 0.65
Phosphorus shall not exceed	0.085	0.085	0.085
Silicon " " "	0.20	0.20	0.20
Sulphur " " "	0.075	0.075	0.075
Manganese	0.75 to 1.00	0.80 to 1.05	0.80 to 1.05

"*Drop Test.*—One drop test shall be made on a piece of rail, not less than 4 ft. and not more than 6 ft. long, selected from each blow of steel. The test piece shall be taken from the top of the ingot. The rails shall be placed head upward on the supports, and the various sections shall be subjected to the following impact tests under a free falling weight:

70 to 79-lb. rails	18 ft.
80 to 89-lb. rails	20 "
90 to 100-lb. rails	22 "

"If any rail breaks, when subjected to the drop test, two additional tests may be made of other rails from the same blow of steel, also taken from the top of the ingots, and if either of these latter rails fail, all the rails of the blow which they represent will be rejected, but if both of these additional test pieces meet the requirements, all the rails of the blow which they represent will be accepted.

"The drop-testing machine shall have a tup of 2 000 lb. weight, the striking face of which shall have a radius of not more than 5 in., and the test rail shall be placed head upward on solid supports 3 ft. apart. The anvil block shall weigh at least 20 000 lb., and the supports shall be part of, or firmly secured to, the anvil. The report of the drop test shall state the atmospheric temperature at the time the test was made.

"*Section.*—The section of rail shall conform, as accurately as possible, to the templet furnished by the railroad company, consistent with the paragraph relative to specified weight. A variation in height of $\frac{1}{64}$ in. less, or $\frac{1}{32}$ in. greater than the specified height, and $\frac{1}{16}$ in. in width will be permitted. The section of rail shall conform to the finishing dimensions.

"*Weight.*—The weight of the rails will be maintained as nearly as possible, after complying with the preceding paragraph, to that specified in contract. A variation of one-half of 1% for an entire order will be allowed. Rails will be accepted and paid for according to actual weights.

"*Length.*—The standard length of rails shall be 33 ft. Ten per cent. of the entire order will be accepted in shorter lengths varying

Report of Committee on Rail Sections (continued).

by even feet to 27 ft., and all No. 1 rails less than 33 ft. long shall be painted green on the ends. A variation of ¼ in. in length from that specified will be allowed.

"*Drilling.*—Circular holes for splice bars shall be drilled in accordance with the specifications of the purchaser. The holes shall conform accurately to the drawing and dimensions furnished, in every respect, and must be free from burrs.

"*Straightening.*—Care must be taken in hot-straightening the rails, and it must result in their being left in such condition that they shall not vary throughout their entire length more than 5 in. from a straight line in any direction, when delivered to the cold-straightening presses. Those which vary beyond that amount, or have short kinks, shall be classed as second-quality rails and be so stamped.

"Rails shall be straight in line and surface when finished—the straightening being done while cold—smooth on head, sawed square at ends, variation to be not more than $\frac{1}{32}$ in., and, prior to shipment, shall have the burr occasioned by the saw cutting removed, and the ends made clean. No. 1 rails shall be free from injurious defects and flaws of all kinds.

"No. 2 rails shall be accepted up to 5% of the whole order. They shall not have flaws in their heads of more than ¼ in., or in the flange of more than ½ in. in depth, and, in the judgment of the inspector, these shall not be so numerous or of such a character as to render them unfit for recognized second-quality rail uses. The ends of No. 2 rails shall be painted white, and shall have two prick-punch marks on the side of the web near the heat number brand, and placed so as not to be covered by the splice bars. Rails from heats which failed under the drop-test shall not be accepted as No. 2 rails.

"*Branding.*—The name of the maker, the weight of the rail, and the month and year of manufacture, shall be rolled in raised letters on the side of the web; and the number of the blow shall be plainly stamped on each rail where it will not subsequently be covered by the splice bars.

"*Inspection.*—The inspector representing the purchaser shall have free entry to the works of the manufacturer at all times when the contract is being filled, and shall have all reasonable facilities afforded him by the manufacturer to satisfy him that the finished material is furnished in accordance with the terms of these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment.

"The manufacturer shall furnish the inspector, daily, with carbon determinations for each blow, and a complete chemical analysis every 24 hours, representing the average of the other elements contained in the steel, for each day and night turn. These analyses shall be made on drillings taken from small test ingots. On the request of the inspector, the manufacturer shall furnish drillings for check analyses.

"*For Basic Open-Hearth Rails.*—The specifications for rails made by the Basic Open-Hearth process shall be the same as for Bessemer rails, excepting that a full chemical determination shall be furnished

for each heat and two drop tests from each. Their chemical composition shall be:

	70 to 79 lb. Percentage.	80 to 89 lb. Percentage.	90 to 100 lb. Percentage.
Carbon	0.53 to 0.63	0.58 to 0.68	0.65 to 0.75
Phosphorus shall not exceed	0.05	0.05	0.05
Silicon " " "	0.20	0.20	0.20
Sulphur " " "	0.06	0.06	0.06
Manganese	0.75 to 1.00	0.80 to 1.05	0.80 to 1.05

"Respectfully submitting the above report, we remain,

"JOSEPH T. RICHARDS, *Chairman;*
"CHAS. W. BUCHHOLZ,
"S. M. FELTON,
"JOHN D. ISAACS,
"R. MONTFORT,
"H. G. PROUT,
"GEO. E. THACKRAY,
"E. K. TURNER,
"WM. R. WEBSTER,
"ROBERT W. HUNT, *Secretary.*"

THE CHAIRMAN.—You have heard the report of the Committee on Rail Sections. This is open to discussion, but not for any action before this meeting. Is there any discussion on this report?

Is there any new business before the meeting? Nothing being moved, I will state that this completes the business for the day.

I will ask the Secretary to make some announcements.

The Secretary and Mr. Moler made announcements as to the programme for the next day, and also for the remainder of the time which the members will spend in Mexico.

Adjourned.

THIRTY-NINTH ANNUAL CONVENTION.

EXCURSIONS AND ENTERTAINMENTS.

The arrangements for the Convention were in the hands of the following Committees:

Committee of the Board of Direction.

A. L. Bowman
J. Waldo Smith
Chas. Warren Hunt

Local Committee of Arrangements.

William G. Moler

John B. Body — S. J. Fortin
T. A. Corry — Roberto Gayol
E. H. Drury — Lewis Kingman

Entertainment at St. Louis.

A special train, to leave St. Louis on the morning of July 4th, 1907, had been arranged for, and the Engineers' Club of St. Louis, through its President, Mr. E. R. Fish, kindly invited all those who arrived in St. Louis on the evening of July 3d to a dinner at the Cherokee Garden. Accordingly, at 7.30 p. m., special cars were waiting for the party at the Southern Hotel, and, accompanied by a committee of the hosts, a special run was made to the place of entertainment. Here a most delightful social evening was passed, and the return made to the Hotel by special cars. This entertainment, which was held in the open air, made a very agreeable break in a somewhat long journey.

Arrival in Mexico City.

Sunday, July 7th, 1907.—The special train was scheduled to arrive in the City of Mexico on the evening of Saturday, July 6th, but the schedule was not adhered to by the railroads, and the party did not reach Mexico City until about midday on Sunday, July 7th. Notwithstanding the uncertainty of the time of arrival, the party was met by representatives of the various engineering organizations and of the Government, and given a most hearty welcome, the effect of which was not lessened by the presence at the station of a fine military band which rendered a number of American national airs.

Excursion about Mexico City.

Monday, July 8th, 1907.—At 9 a. m. the party met at the Mineria (Engineers' School and Mines Building), which, through the

courtesy of Hon. Leandro Fernandez, Minister of Public Works, was placed at the disposal of the Society for Headquarters, meeting room, etc., and, taking the seven waiting special trolley cars, as guests of the Street Railway Company of Mexico, Mr. R. C. Brown, General Manager, visited a number of the suburbs of the City, passing through Zocalo, and thence to Guadalupe where the party remained an hour, thence returning *via* Zocalo, and running out to Tlalpam, one of the beautiful suburbs, where about half an hour was spent. After leaving Tlalpam, the excursion reached Churubusco, where the entire party, which included not only the American visitors but many members of Mexican engineering organizations and their ladies, and numbering about 300, was entertained at luncheon, which occupied about two hours, after which the cars were again boarded, and the trip continued to San Angel, *via* Coyoacan, thence to Chapultepec, and to the Power-House of the Street Railway Company, returning after that to the starting point at the Mineria.

New City Water-Works.

Tuesday, July 9th, 1907.—A start was made from the Mineria by special cars at 8.30 A. M., and the route lay *via* Zocalo to Chapultepec, where the reservoirs were inspected, after which a special train was boarded for the run to Xochimilco. Stops were made at frequent intervals for the inspection of the new concrete aqueduct.

Xochimilco, where one of the springs forming the source of supply is located, was reached at 1.30 P. M., and luncheon was served in a shelter beautifully decorated with floral emblems for the occasion. The hosts of the day were the Water-Works Commission, and the Chief Engineer of the Works, Manuel Marroquin, M. Am. Soc. C. E. The return was made to Chapultepec at 6 o'clock, where the electric car specials awaited the party for the return to the Mineria.

Meetings of the Society.

Wednesday, July 10th, 1907.—The day was devoted to meetings for the discussion of professional topics. Three meetings were held.

Trip to Necaxa.

Thursday, July 11th, 1907.—By invitation of the Mexican Light and Power Co., Ltd., Mr. R. F. Hayward, General Manager, the members of the Society, and other guests, met at the station of the Hidalgo and Northeastern Railroad at 6.30 A. M., where a special train was waiting for the run to Carmen, the first camp of the Company. Breakfast was served on the train, and lunch was served at Carmen, after which a train of flat-cars, on which careful

preparations had been made for the seating of the party as well as for their protection from the rain which is at times almost inevitable in this locality, was boarded. The trip from Carmen to Necaxa (about 29 km.) was over the Company's narrow-gauge railroad, and afforded during its whole length views of some of the most beautiful mountain scenery in Mexico. Necaxa was reached about 4 P. M., and those who were adventurous enough started to inspect the work in progress, notwithstanding the rain.

After dinner had been served, an informal dance was organized in which all participated.

Friday, July 12th, 1907.—The morning was spent in the inspection of the dam, which is being built at Necaxa by the hydraulic-fill process, and of the pressure pipe line and power-house. All the party visited the power-house, some going down and up in the cages while others rode down and up the trail on horseback. Luncheon was served at Necaxa, and the party arrived in Mexico at 11 P. M.

The total number on this trip was about 110.

Reception by President Diaz.

Saturday, July 13th, 1907.—Meeting at the Mineria at 8.30 A. M., the party took special cars for the National Palace where at 9.30 they were received by His Excellency, Porfirio Diaz, President of the Mexican Republic, the party being introduced by Hon. Leandro Fernandez, Minister of Public Works, in a short speech, which was responded to by the President, who welcomed the party to Mexico and who expressed his pleasure at seeing them.

At 1 P. M., the party was entertained at a banquet at Chapultepec by the Society of the Military College and the Mexican Association of Engineers and Architects. Many distinguished Mexican engineers, both civil and military, were present. Music was furnished for the occasion by two bands, and addresses were made by Señor Ignacio de la Barre, President of the Military College, and Señor J. Ramón Ibarrola, representing the Mexican Association of Engineers and Architects, and by Onward Bates, Vice-President, Am. Soc. C. E.

In the evening, the Annual Session of the Society of the Military College was held in the Mineria, the entire building being specially decorated and illumined for the occasion. This meeting was dedicated to the American Society of Civil Engineers, and Onward Bates, Vice-President, Am. Soc. C. E., presided as Honorary President. At this meeting, addresses were made by Brig.-Gen. Beltran, Director of the National Military College, Señor Roberto Dominguez, Postmaster-General of Mexico, and

Señor Luis G. Leon. In addition to the speechmaking, three musical numbers were rendered by the Artillery and Police bands.

After the meeting an elaborate supper was served on the balcony of the patio of this beautiful building.

Sunday, July 14th, 1907.—Facilities were furnished by the Local Members for all members of the party to visit the French celebration of the Fall of the Bastile, and an exhibition of the Spanish game of Pelota.

Excursion to the Drainage Works.

Monday, July 15th, 1907.—The party met at the Mineria at 6.30 A. M., and proceeded by special trolley cars to the Peralvillo Station of the Hidalgo and Northeastern Railway. Thence, as guests of the Mexican Government, the party boarded a special train, made up for the occasion, and started at 7.30 A. M. for the inspection of the Drainage Works of the Valley of Mexico. A stop of nearly an hour was made for the inspection of the sluice gates of Lake Texcoco, after which stops were made at San Cristobal, at the bridge of San Pedro, at Shaft No. 1, and at the entrance to the Drainage Tunnel at Tequixquiac. At the last stop an elaborate banquet, presided over by Señor Ibarrola, was served, and the special train started on the return at 4 P. M. reaching the Hidalgo and Northeastern Station in Mexico at about 8 P. M.

At 10 P. M. the party again took cars at the station of the Mexican Railway and started for a trip to Orizaba.

Trip to Orizaba.

Tuesday, July 16th, 1907.—The special train, which was kindly furnished through the courtesy of the Mexican Railway, reached Esperanza early in the morning, and members of the party were entertained at breakfast in the station by the Mexican membership, after which the trip was resumed in an observation train, Orizaba being reached at 11 A. M. After a short stop, the train proceeded as far as Fortin, where the coffee groves and banana plantations, and the hacienda of Las Animas were visited. Returning, no stop was made at Orizaba, but the train was run back to Rio Blanco, where luncheon was served in the Assembly Hall of the Compañia Industrial. After luncheon the party visited the cotton mills, but owing to the lateness of the hour and to the inclemency of the weather, a visit to the town of Orizaba, which had been planned, was abandoned. The party left Rio Blanco at 4 P. M., arriving at Esperanza in time for dinner, and leaving there at 10.30 P. M. for the return trip to Mexico, which was reached at 5.30 A. M., Wednesday, July 17th.

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At 10 P. M. the party again took cars at the station of the Mexican Railway and started for a trip to Orizaba.

Trip to Orizaba.

Tuesday, July 16th, 1907.—The special train, which was kindly furnished through the courtesy of the Mexican Railway, reached Esperanza early in the morning, and members of the party were entertained at breakfast in the station by the Mexican membership, after which the trip was resumed in an observation train, Orizaba being reached at 11 A. M. After a short stop, the train proceeded as far as Fortin, where the coffee groves and banana plantations, and the hacienda of Las Animas were visited. Returning, no stop was made at Orizaba, but the train was run back to Rio Blanco, where luncheon was served in the Assembly Hall of the Compañia Industrial. After luncheon the party visited the cotton mills, but owing to the lateness of the hour and to the inclemency of the weather, a visit to the town of Orizaba, which had been planned, was abandoned. The party left Rio Blanco at 4 P. M., arriving at Esperanza in time for dinner, and leaving there at 10.30 P. M. for the return trip to Mexico, which was reached at 5.30 A. M., Wednesday, July 17th.

Excursion to Cuernavaca.

Wednesday, July 17th, 1907.—Without returning to their hotels, the party took breakfast at the Mexican station, and began the trip to Cuernavaca (as guests of the Mexican membership of the Society) at 7 A. M. On arrival at Cuernavaca, lunch was served at the Hotels Bella Vista and Morelos, and after visiting the many points of interest, the return was made to Mexico in the late afternoon.

Special Trip to the Isthmus of Tehuantepec.

A party of eighteen accepted the kind invitation of Messrs. S. Pearson and Son, Ltd., to be their guests on a trip to visit the Port Works, now under construction on the Isthmus of Tehuantepec. This party left the main party on Tuesday afternoon at Rio Blanco. A special car having been placed at their disposal, A. Peimbert, M. Am. Soc. C. E., acting for the hosts, took charge of the party. The car left Rio Blanco at 3.30 P. M., and was run to Orizaba where, under the guidance of S. W. Stacpoole, M. Am. Soc. C. E., two or three hours were agreeably spent in seeing this beautiful town. The night was spent in the car at Cordoba, and the next morning the journey was resumed over the Vera Cruz and Pacific Railroad, Tierra Blanca being reached by midday. Here it was ascertained that excessive rains had caused a washout farther down the line, which made a delay of 24 hours necessary, and, to occupy this time, the car was run from Tierra Blanca to Vera Cruz, which was reached in time to give ample opportunity to see this interesting place. In the morning, the trip was resumed, and, after one more night spent on the road, Santa Lucretia, on the Tehuantepec Railroad, was reached on the morning of Friday. Coatzacoalcos was reached in the early afternoon of Friday, July 19th, and the party was here met by the engineers and other officers of the Company, and work in progress was inspected during the afternoon. The entire party was entertained at dinner, and on the morning of Saturday, July 20th, the trip from Coatzacoalcos across the Isthmus was begun, Tehuantepec being reached in the early afternoon. The balance of the day, and the morning of Sunday, was spent in this very interesting Indian town, and Salina Cruz was reached at midday. Here again special preparations had been made for the inspection of the extensive Port Works, and the afternoon was devoted to this purpose. In the evening the return trip was started, Cordoba being reached in the late afternoon of Monday, July 22d. This gave an opportunity of visiting, both in the afternoon and in the early morning, this beautiful town, and the return trip was made without accident to the City of Mexico, which was reached in the evening of Tuesday, July 23d.

Those whose privilege it was to make this trip were delighted with it. The weather was very good at all times, and never excessively hot. This was a most agreeable surprise, as all had been led to believe that the trip at this season would be uncomfortable and probably dangerous to health. No inconvenience whatever was had from mosquitoes, the arrangements for the care of the party were perfect, and the works visited (the Tehuantepec Railroad, as well as the Port Works at each end) were found of great interest.

Acknowledgment of Courtesies.

It has been impossible to give in detail in this account the many courtesies to the Society as a whole, or to indicate the many personal kindnesses received by individual members during this Convention. There was such hearty co-operation in the welcome, and in the preparations made for the entertainment and instruction of the visiting party, that it has been impossible to acknowledge each particular courtesy extended. It is therefore felt that a general acknowledgment should be here made to every one who assisted in the entertainment, on behalf of the Society as a body, and of all those who were fortunate enough to be able to attend this Convention.

Among those to whom special acknowledgment is due are the following:

To President Porfirio Diaz, for his cordial welcome, and for the interest manifested by him in the visit of the Society to Mexico;

To the Mexican Society of Engineers and Architects, and to Señor Leandro Fernandez, its President;

To the Society of the Military College, and to Señor Ignacio de la Barre, its President; and also to Señor Joaquin Baltran, Director.

To the Sociedad "Antonio Alzate";

To the St. Louis Engineers' Club, M. E. R. Fish, President, for a very pleasant evening spent in St. Louis, *en route* for Mexico;

To the Electrical Street Railway Company of Mexico (Mr. R. C. Brown, Gen. Mgr.), for its courtesy in issuing to every member of the party a special pass good at all times on any of its cars, from the arrival of the party in Mexico until August 1st; as well as for the special cars furnished every day during the stay of the party in the City;

To the Water-Works Commission of the City, Manuel Marroquin, M. Am. Soc. C. E., Chief Engineer, for the interesting visit to the work in progress, and for the delightful banquet at Xochimilco;

To the Mexican Light and Power Company, Ltd., R. F. Hayward, M. Am. Soc. C. E., Gen. Mgr., for the two days' excursion to its interesting works at Necaxa;

To the Mexican Railway, and to Mr. Walter Morcom, for free transportation on the trip to Orizaba, and for other courtesies extended;

To the Mexican Central Railway, and to Mr. C. R. Hudson;

To the American, British, Spanish, and Country Clubs, of the City of Mexico, for their hospitality to all the visiting members;

To the Hydrographic Commission of the Republic of Mexico, and to Señor J. Ramón Ibarrola, Director, for the interesting excursion to the drainage works of the Valley;

To S. Pearson and Son, Ltd., John B. Body, M. Am. Soc. C. E., Director, for the very interesting seven-day trip to the Isthmus of Tehuantepec;

To all members of the Society residing in Mexico who aided so much in the entertainment of the visiting members, and last, but by no means least, to the Local Committee of Arrangements, who planned so carefully, and executed so well, the whole delightful programme.

THE ATTENDANCE AT THE THIRTY-NINTH ANNUAL CONVENTION.

The following 84 members were in attendance:

Adam, Robert .....Mexico City
Adams, Frederick,
Salina Cruz, Mexico
Alvord, John W...Chicago, Ill.
Anderson, J. T. Noble,
Belfast, Ireland
Andrews, Horace..Albany, N. Y.
Archbald, James..Scranton, Pa.

Baker, Ira O..Champaign, Ill.
Baldwin, W. J..New York City
Ball, Charles B....Chicago, Ill.
Bates, Onward.....Chicago, Ill.
Bayliss, J. Y....St. Louis, Mo.
Beach, L. H.,
Fort Leavenworth, Kans.
Bienenfeld, Bernard,
San Francisco, Cal.
Blackford, F. W...Mexico City
Body, J. B.....Mexico City
Bowman, A. L..New York City
Breuchaud, Jules,
Park Hill, N. Y.
Buxton, Clifford..Toledo, Ohio

Campbell, J. L....El Paso, Tex.
Clayton, R. M.....Atlanta, Ga.
Coe, D..Rincon Antonio, Mexico
Connor, E. H.,
Leavenworth, Kans.
Cook, John H..Paterson, N. J.
Corry, T. A.....Mexico City
Crowell, Francis S.,
Purcell, Ind. T.

Deyo, S. L. F..New York City

Earley, J. E.....Mexico City

Follet, W. W....El Paso, Tex.
Fortin, S. J.....Mexico City
Freeman, John R.,
Providence, R. I.
Frisell, E. H.....Mexico City
Fuller, W. B....New York City

Gardiner, J. P....Indé, Mexico
Gardner, W. M..Memphis, Tenn.
Gayol, Roberto....Mexico City
Greene, A. E..Ann Arbor, Mich.

Hallsted, James C..Chicago, Ill.
Henderson, S. W..Durango, Col.
Hill, Walter A.,
Churubusco, Mexico
Hitchman, J. C..Ocatlan, Mexico
Hodge, Henry W.,
New York City
Holmes, E. M..Daiquiri, Cuba
Howe, J. M.....Houston, Tex.
Hunt, Charles Warren,
New York City
Hyde, A. Lincoln,
Columbia, Mo.

Jonah, F. G..New Orleans, La.

Keith, Herbert C.,
New York City
Kerr, Frank M.,
New Orleans, La.
Kingman, Lewis...Mexico City

Leonard, H. R..Philadelphia, Pa.
Lewis, Nelson P..New York City
Lewis, Sidney F.,
New Orleans, La.
Lynch, M. L.....Tyler, Tex.

McCurdy, John E.,
Oaxaca, Mexico
Marroquin y Rivera, M.,
Mexico City

Mathewson, T. K.,
Puruandiro, Mexico
Melvin, D. N.,
Linoleumville, N. Y.
Merriman, Mansfield,
Bethlehem, Pa.
Meyer, R.....Monterey, Mexico
Moler, W. G.....Mexico City
Myers, William M.,
Puebla, Mexico

Nauman, George,
Philadelphia, Pa.
Northrop, Albert A.,
Brown Station, N. Y.

Ortiz, Eduardo.....Mexico City

Peimbert, A.....Mexico City
Pew, Arthur.....Atlanta, Ga.
Polk, W. Anderson,
New York City
Potter, H. W..Torreon, Mexico
Puga, Guillermo Beltran y,
Mexico City

Richardson, J. H.,
New York City
Ridgway, Robert,
Poughkeepsie, N. Y.
Russell, S. Bent..St. Louis, Mo.
Ryder, Ely M. T.,
New Haven, Conn.

Selmer, J. K.....Mexico City
Sherrerd, M. R...Newark, N. J.
Smith, G. E. P...Tucson, Ariz.
Smith, J. Waldo..New York City
Smith, James,
Coatzacoalcos, Mexico
Stacpoole, S. W.,
Orizaba, Mexico
Stuart, J. T..Philadelphia, Pa.
Sundstrom, A. Y...Mexico City

Tribus, Louis L..New York City
Turner, N...Monterey, Mexico

Williams, G. S.,
Ann Arbor, Mich.

There was also present a large number of ladies of the families of members, and many Mexican engineers, members of the Mexican Association of Engineers and Architects, of the Association of the Military College, and of the Sociedad "Antonio Alzate."

In addition to this, Special Delegates to the Convention were sent by the Governors of Yucatan, Puebla, and Vera Cruz.

It is impossible to state the total attendance at this Convention accurately, but it is estimated that the total number participating in the various meetings and excursions was not far from 500.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, September 4th, 1907.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper entitled "Comparison of Rainfall and Run-Off in the Northeastern United States," by John C. Hoyt, Assoc. M. Am. Soc. C. E., will be presented for discussion.

This paper was printed in *Proceedings* for May, 1907.

Wednesday, September 18th, 1907.—8.30 P.M.—At this meeting a paper entitled "A Description of the Recently Installed Sewage Disposal Works for the Village of Ballston Spa, New York," by G. L. Robinson, Assoc. M. Am. Soc. C. E., will be presented for discussion.

This paper was printed in *Proceedings* for May, 1907.

Wednesday, October 2d, 1907.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and two papers will be presented for discussion, as follows: "Reinforced Concrete Towers," by D. W. Krellwitz, Jun. Am. Soc. C. E.; and "Reinforced Concrete Pipe for Carrying Water Under Pressure," by Chester Wason Smith, Assoc. M. Am. Soc. C. E.

These papers are printed in this number of *Proceedings*.

Wednesday, October 16th, 1907.—8.30 P. M.—At this meeting a paper entitled "The Bracing of Trenches and Tunnels, With Practical Formulas for Earth Pressures," by J. C. Meem, M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings*.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all meetings:

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Society of Engineers, 17 Victoria Street, Westminster, S. W., England.

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Civil Engineers' Club of Cleveland, 718 Caxton Building, Cleveland, Ohio.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa.

Engineers' Society of Western Pennsylvania, 803 Fulton Building, Pittsburg, Pa.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

Louisiana Engineering Society, 604 Tulane-Newcomb Building, New Orleans, La.

Engineers' Club of Central Pennsylvania, Corner Second and Walnut Streets, Harrisburg, Pa.

Engineers' and Architects' Club of Louisville, Ky., 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

Teknisk Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Société des Ingénieurs Civils de France, 19 Rue Blanche, Paris, France.

Svenska Teknologförenigen, Brunkebergstorg 18, Stockholm, Sweden.

Institute of Marine Engineers, 58 Romford Road, Stratford, London, E., England.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Pacific Northwest Society of Engineers, 617–618 Pioneer Building, Seattle, Wash.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Memphis Engineering Society, Memphis, Tenn.

Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

The Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Institution of Engineers of the River Plate, Buenos Aires, Argentine Republic.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.
Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.
Cleveland Institute of Engineers, Middlesbrough, England.
Civil Engineers' Society of St. Paul, St. Paul, Minn.
Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.
Rochester Engineering Society, Rochester, N. Y.
Brooklyn Engineers' Club, 197 Montague Street, Brooklyn, N. Y.
Montana Society of Engineers, Butte, Montana.

SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

In reference to this work, the Appendix* to the Annual Report of the Board of Direction for the year ending December 31st, 1906, contains a summary of all searches made to that date.

* *Proceedings*, Vol. XXXIII, p. 20 (January, 1907).

ACCESSIONS TO THE LIBRARY.

From May 7th to August 7th, 1907.

DONATIONS.*

SETTING OUT OF TUBE RAILWAYS.

By G. M. Halden. Cloth, 11 x 8½ in., illus., 68 pp. London, E. & F. N. Spon, Ltd.; New York, Spon & Chamberlain, 1907. $4.00.

The contents of this book appeared originally as a series of articles in *The Engineer*. Practical details on the setting out and construction of tube railways, which have been confirmed by actual experience by the author, only are described, all matter not bearing distinctly on the subject being omitted. The author assumes a knowledge of trigonometry and the use of the theodolite on the part of the reader. The Contents are: Preliminary Survey of Tube Railways; Instruments and Setting Out Appliances; Adjustment of Instruments; Levelling; Setting Out at Poole Street Shaft; Fixing Reels for Heavy Bobs; Starting Shield on Twenty-Chain Curve; Setting Out Tunnels with Wire Stretched in Bottom of Heading; Description of Seventeen-Chain Curve; Traverse I, from Poole Street to Old Street; Traverse II, from Essex Road to Drayton Park; Permanent Way; Blackwall Tunnel under Compressed Air; Sounding the River on Site of Tunnel; London County Council Sewer Tunnel; Traverse V, from Elliott Place to Van Brugh Park; Traverse VI from Van Brugh Park to Siebert Road; Page of Don'ts. There is an index of two pages.

THE MECHANICS OF HOISTING MACHINERY.

Including Accumulators, Excavators, and Pile-Drivers. Text-Book for Technical Schools and a Guide for Practical Engineers. By Dr. Julius Weisbach and Professor Gustav Herrmann. Authorized Translation from the Second German Edition, by Karl P. Dahlstrom. Cloth, 9 x 6 in., illus., 8 + 332 pp. New York, The Macmillan Company; London, Macmillan & Co., Ltd., 1907. $3.00 net.

Several volumes of Weisbach's work on Engineering Mechanics have been made familiar to English readers through the translations of Messrs. Coxe, Du-Bois and Klein. The present volume is translated from Professor Herrman's revised edition of Weisbach's work, and has never before been published in the English language. The book, as stated on the title-page, is intended as a text-book for students in the more advanced courses in the mechanics of machinery, and as a guide to practical engineers. References, in the text, to previous volumes of Weisbach's Mechanics, are to the English translations, unless otherwise specified. Both metric and English measurements are given, the latter being enclosed in brackets. The Contents are: Levers and Jacks; Tackle and Differential Blocks; Windlasses, Winches, and Lifts; Hydraulic Hoists, Accumulators, and Pneumatic Hoists; Hoisting Machinery for Mines; Cranes and Sheers; Excavators and Dredges; Pile-Drivers. There is an index of two pages.

THE CHEMISTRY AND TECHNOLOGY OF MIXED PAINTS.

By Maximilian Toch, Assoc. Am. Soc. C. E. Cloth, 9½ x 6 in., illus., 16 + 166 pp. New York, D. Van Nostrand Company, 1907. $3.00 net. (Donated by the Author.)

This book is intended as a reference work, on the science and technology of modern paints, for the student in chemistry, the engineer, the paint manufacturer and paint chemist, all of whom are supposed by the author to have had previous knowledge or training in the subject. Some of the subject-matter has been extracted from lectures delivered by the author at various universities and before scientific bodies, but most of it is here published for the first time. The first nine chapters are devoted to a discussion of the machinery necessary in the manufacture of mixed paints and the raw materials most generally used in such manufacture. Under the chapters on Pigments the author has omitted all mention of such as are rarely used, or gone out of use. He also advocates the

*Unless otherwise specified, books in this list have been donated by the publisher.

proper labelling as to the constituents of mixed paints by manufacturers. There is a chapter on the chemical technology of linseed oil, followed by chapters on the manufacture of various driers used for paint purposes. Combining mediums and water in the composition of mixed paints is next discussed, followed by chapters on special paints for floors, etc., and on the analysis of mixed paints. There is an appendix containing a translation of a Consular report on the Chinese oil tree. The Contents are: The Manufacture of Mixed Paints; The Pigments; Yellow, Blue and Green Pigments; The Inert Fillers and Extenders; Paint Vehicles; Special Paints; Analytical; Consular Reports on China Wood Oil. There is an Index of four pages.

THE DESIGN OF WALLS, BINS AND GRAIN ELEVATORS.

By Milo S. Ketchum, Assoc. M. Am. Soc. C. E. Cloth, 9 x 6½ in., illus., 16 + 393 pp. New York, The Engineering News Publishing Co.; London, Archibald Constable & Company, 1907. $4.00 net. (Donated by the Author.)

A presentation of a systematic analysis of the stresses due to granular materials, together with a discussion of the principles of design and the details of structures for holding such materials, has been the object of this book, according to the author. The first part of the book is devoted to the design of retaining walls, a knowledge of the theory of retaining walls being necessary to an understanding of the theory of pressure in bins. The design of bins for coal, ore, etc., is taken up and studied in the second part of the book, followed by a discussion of the design of grain bins and elevators. Graphic methods have been used for calculating the pressures on retaining walls and in hopper bins, as well as algebraic methods for calculating stresses. The theory of reinforced concrete, now used extensively in the construction of retaining walls, bins, and grain elevators, is discussed, and formulas necessary for use in the design of such structures are developed. All the available experiments on the pressure of granular materials have been included by the author. The subject of costs has been thoroughly considered, and examples of actual construction are given in detail. The Contents are: Part I, The Design of Retaining Walls; Rankine's Theory; Coulomb's Theory; Design of Masonry Retaining Walls, Reinforced Concrete Retaining Walls; Experiments on Retaining Walls; Examples of Retaining Walls; Cost of Retaining Walls. Part II, The Design of Coal Bins, Ore Bins, etc.; Types of Coal Bins, Ore Bins, etc.; Stresses in Bins; Experiments on Pressures on Bin Walls; The Design of Bins; Examples and Details of Bins; Cost of Bins; Methods of Handling Materials. Part III, The Design of Grain Bins and Elevators; Types of Grain Elevators; Stresses in Grain Bins; Experiments on the Pressure of Grains in Deep Bins; The Design of Grain Bins and Elevators; Examples of Grain Elevators; Cost of Grain Bins and Elevators. There are two Appendices and an Index of five pages.

PRACTICAL ILLUMINATION.

By James Raley Cravath and Van Rensselaer Lansingh. Cloth, 9½ x 6 in., illus., 7 + 356 pp. New York, McGraw Publishing Company, 1907. $3.00 net.

In these pages no attempt has been made to treat of the apparatus for the production of light, specific data and suggestions of how best to use the light for interior illumination only being given. In Part I the effects produced by various deflectors, shades and globes are discussed, together with the effects on the eye by different arrangements of artificial lighting. A number of tests of the light-distribution of various illuminants, with different reflectors and shades are also given. Almost all these tests were made at the Electrical Testing Laboratories of New York City, no tests made by manufacturers being given. In the Appendix are given many of the manufacturers' names and numbers, or trade designations, of the reflectors, shades and globes tested. Part II is devoted to practical examples of rooms of various kinds with both good and bad lighting arrangements, the desirable and undesirable features of every case being fully discussed. The Contents are: Introduction; The Laws and Measurement of Light; Light and the Eye; Calculation of Illumination; Individual Incandescent Electric Lamps and Their Reflectors, Shades and Globes; Individual Gas Burners and Their Reflectors, Shades and Globes; Acetylene Gas Burners and Their Shades; Incandescent Electric Lamp Clusters and Bowls; Nernst Lamps and Their Globes; Electric Arc Lamps; Gas Arc Lamps; Vapor Lamps; Demonstration Room Tests; Comparison of Illuminants; Introduction to Practical Examples; Residence Lighting; Desk, Drafting Room and Office Lighting; The Lighting of Public Halls and Lodge Rooms; The Lighting of Large Dining and Banquet Rooms; The Lighting of Large Public Rooms, Depots, Lobbies, etc.; The Lighting of

Halls and Corridors of Large Office Buildings; The Lighting of Theaters; The Lighting of Churches; The Lighting of Libraries, Reading and School Rooms; Car Lighting; Store Lighting; Show Window Lighting; Shop and Factory Lighting; Miscellaneous Examples of Lighting; Appendix. There is an index of eight pages.

THE ENGINEERING INDEX ANNUAL FOR 1906.

Compiled from the Engineering Index Published Monthly in *The Engineering Magazine* during 1906. Cloth, 9½ x 6½ in., 14 + 395 pp. New York and London, The Engineering Magazine, 1907. $2.00.

This volume is a continuation of the work edited and published, in 1884, by The Association of Engineering Societies, under the direction of the late J. B. Johnson, M. Am. Soc. C. E. The first index was followed by others in 1892, 1896, 1902 and 1906, respectively. As much of the literature of modern engineering becomes obsolete in five years, the time required to edit, and publish the previous volumes, it has been decided to continue the publication as an annual. The contents of the earlier indexes were arranged alphabetically by subject. This volume, however, following the arrangement of the engineering index published monthly by *The Engineering Magazine*, is classified under the several divisions of engineering practice—Civil, Electrical, Marine and Naval, Mechanical, Mining, and Railway Engineering. These main divisions are divided into the special classes which come under them, these entries being arranged alphabetically. Under each entry a brief abstract, showing the scope and purport of the article, is given. Serials are indexed under the first instalment only, except in case of short articles. This index has been brought down to the end of 1906, but a monthly continuation of it may be found in the issues of *The Engineering Magazine*.

HYDROMETALLURGY OF SILVER.

With Special Reference to Chloridizing Roasting of Silver Ores and the Extraction of Silver by Hyposulphite and Cyanide Solutions. By Ottokar Hofmann. Cloth, 9 x 6 in., illus., 10 + 345 pp. New York and London, Hill Publishing Company, 1907. $4.00.

In his treatment of this subject, the author has divided the book into two parts. The first part relates to the "Chloridizing Roasting of Silver Ores." This is stated to be the most important metallurgical operation in the hydrometallurgy of silver, the subsequent extraction of the silver by the solvent depending entirely on the quality of the roasting. Under this general heading the author takes up and discusses the Theory of Chloridizing Roasting; Crushing of the Ore; Percentage of Salt Required; Loss of Silver by Volatilization; Methods of Roasting; Consumption of Fuel; Reverberatory Furnaces Worked by Hand; Mechanical Roasting Furnaces; Collecting the Flue-Dust; Sulphating Roasting; Chloridizing of Argentiferous Zinc-Lead Ore; Chloridizing of Calcareous Ores. Part II relates to the "Extraction of the Silver" from the roasted ore by different solvents. After a short description of the process, the author discusses the different operations and appliances used, and which he himself has successfully practised in Mexico and the western part of the United States. The chapter headings under this part are: Lixiviation with Sodium Hyposulphite; Precipitation of Silver; Treatment of the Precipitate; Construction of Troughs; Trough Lixiviation; The Russell and Kiss Processes; The Augustin Process; Extraction with Sulphuric Acid; The Ziervogel Process; Treatment of Silver Ores Rich in Gold. In the last chapter, the Cyanidation of Auriferous Silver Ores is discussed. There is an index of sixteen pages.

RAILWAY PROBLEMS.

Edited, with an Introduction. By William Z. Ripley. Cloth, 9 x 6 in., illus., 32 + 686 pp. Boston, Ginn & Company, 1907. $2.25.

This volume is composed of reprints of articles on railway economics, collected from various books and technical journals. The editor, in the preface, states that its purpose is two-fold: "to render more easily accessible to the interested public, valuable technical material upon a question of paramount interest

and importance at the present time," and "to facilitate the work of the college instructor in the economics of transportation." Some of the articles are merely for reference reading, but others, especially the decisions of the Interstate Commerce Commission, provide material which may be debated and discussed in the class room. As economic facts only are discussed by the editor, many of the reprints of the above-named decisions have been stripped of the legal material, which has simplified them for the use of students. It is stated that the book is intended to be used in connection with some standard treatise upon the economics of transportation, in the conduct of courses. The Contents are: A Chapter of Erie (Early speculative and financial scandals); by Hon. Charles Francis Adams. Standard Oil Rebates; by Ida M. Tarbell. The Building and Cost of the Union Pacific (Construction companies); by Henry Kirke White. The Southern Railway & Steamship Association (A typical pool); by Henry Hudson. The Theory of Railway Rates; by Frank W. Taussig. Unreasonable Rates: The Cincinnati Freight Bureau Case; The Maximum Freight Rate Decision; The Savannah Naval Stores Case. Relative Rates: The Hutchinson, Kan., Salt Case; The Eau Claire, Wis., Lumber Case; The Chattanooga Case. The Long and Short Haul Clause: The St. Cloud, Minn., Case; The Savannah Fertilizer Case. The Trunk Line Rate System; by William Z. Ripley. The Southern Basing Point System: The Troy, Ala., Case. The Alabama Midland Decision; The Dawson, Ga., Case. The Southern Rate System: The Danville, Va., Case. Transcontinental Freight Rates: The St. Louis Business Men's League Case. Export and Domestic Rates (Atlantic & Gulf competition). Freight Classification: The Hatters' Furs Case. Economic Waste in Transportation; by William Z. Ripley. The Northern Securities Company (Railroad consolidation); by Balthasar H. Meyer. The Interstate Commerce Law as Amended in 1906; by Frank H. Dixon. Reasonable Rates (Judicial determination); by Alton D. Adams. The Doctrine of Judicial Review; by H. S. Smalley. The English Railway and Canal Commission of 1888; by S. J. McLean. Railway Regulation in France; by W. H. Buckler. Railroad Ownership in Germany; by Balthasar H. Meyer. There is an index of four pages.

PORTS MARITIMES.

Par De Cordemoy. Tome I. Leather, 7 x 5 in., illus., 8 + 576 pp. Paris, H. Dunod et E. Pinat, 1907. 15 francs.

In this first volume, the author treats of the sea, the winds, the waves, etc., the physical side of the subject, and it is stated that this work may be recommended for its practical character, the numerous examples given to support the author's descriptions, and the clearness and exactness of its illustrations. The second volume will treat of the methods of constructing jetties, quays, dikes, the utilization of harbors, etc. The Contents are: Mer; Vents; Ondes Liquides; Vagues; Marées; Les Marées dans les Fleuves; Courants; Côtes; Barres et Deltas; Dragages; Protection des Côtes; Généralités sur les Ports; Etudes d'un Etablissement Maritime; Ports; Ports a Chasses Naturelles; Ports a Moles Convergents; Ports sur Plages de Sable; Ports a Jetées; Fleuves et Estuaires; Matériaux Employés à la Mer; Phares; Bouées; Notions de Cosmographie; Notions de Trigonométrie Sphérique; Notions de Navigation; Hydrographie; Navires.

WATER-WORKS MANAGEMENT AND MAINTENANCE.

By Winfred D. Hubbard, Assoc. M. Am. Soc. C. E., and Wynkoop Kiersted, M. Am. Soc. C. E. Cloth, 9 x 6 in., illus., 6 + 429 pp. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1907. $4.00.

It is stated that the questions relating to the maintenance and operation of a system of water-works often depend, for their proper solution, upon the details of the original design. The authors, therefore, have outlined, in Part I of their book, the various methods of securing a water supply. Part II deals with matters connected with the routine management of a water-works plant. The questions arising in the dealings of municipalities with private water companies are discussed in Part III, and the principles involved in the fixing of water rates and the valuation of water-works property are presented in detail. The Chapter Headings are: Ground-Water Supply; River-Water Supply; Pumping Engines; Impounded Supplies; Plans and Records; Extensions; Service Connections; Meters; Care of Appurtenances; Alterations and Repairs; Maintenance of Quality; Water Waste; Electrolysis; Fire Protection; Accounts; Financial Management; Rules and Regulations; Annual Reports; Franchise, Water Rates, Depreciation. There is an index of eight pages.

CONCRETE-STEEL BUILDINGS.

By W. Noble Twelvetrees. Cloth, 7½ x 5 in., illus., 12 + 408 pp. London, Whittaker & Co., 1907. $3.25 net. (Presented by The Macmillan Co.).

In a previous work, "Concrete-Steel," the author discussed the theory and practice of concrete construction. In this volume he presents detailed particulars of buildings designed for use in Great Britain, on the Continent, and in America, as dock sheds, railway goods stations, locomotive sheds, warehouses, manufactories, workshops, flour mills and granaries, hospitals, hotels, residences, churches, theatres, and public halls. In order to emphasize the necessity for correct design, competent supervision and skillful construction, the last chapter is devoted to descriptions of some failures in concrete-steel construction. An Appendix is added, which contains classified lists of concrete-steel structures erected in the United Kingdom. The Index contains references to details of the buildings described, to data concerning the proportions and consistency of the concrete used, the amount of reinforcement and the strength of materials, the results of tests, contractors' plant, and methods of practical construction.

HOW TO DESIGN A GAS ENGINE.

With Full Working Drawings for a 7 B. H. P. Gas Engine. By Horace Allen. Cloth, 10 x 7½ in., illus., 30 + 1 pp. Manchester, England, The Scientific Publishing Co. 2 shillings 6 pence.

This small volume consists of a description, together with a series of working drawings, of a 7 b. h. p. gas engine of the ordinary single-acting Otto type. The fuel used in this engine is an average quality of ordinary illuminating gas. The chapter headings are: Crank Shaft; Connecting Rod; Cylinder; Water Jacket; Cylinder Liner; The Piston; The Flywheel; Operation of Main Valves; Valve Seats, Valves, and Operating Mechanism; Governors; Spiral or Skew Gear. There is a one-page index.

STRESSES IN STRUCTURES.

And the Accompanying Deformations. By A. H. Heller. Cloth, 9 x 6 in., illus., 324 pp. Columbus, Ohio, 1907. $4.00. (Presented by A. G. Geren, Agent, Eugene Dietzgen Company.)

The manuscript of this work was used by Professor Heller in his classes at the Ohio State University. It is intended both as a reference book for the profession and as a textbook for schools. The book, as it is here presented, covers stresses in all forms of simple trusses; but it is stated that it was the intention of the author, had he lived to finish the work, to cover also the common forms of statically indeterminate structures as well as the three-hinged arch and cantilever bridges, as shown by frequent references to chapters which are not included in the book. The Contents are: Stresses and Deformations Within the Elastic Limit; Stresses and Deformations Beyond the Elastic Limit; The Laws of Equilibrium and Their Application; Application of the Laws of Equilibrium to the Structures as a Whole; Reactions; Application of the Laws of Equilibrium to any one Joint; Application of the Laws of Equilibrium to a Part of a Structure; Stresses in Beams and Girders; Deflection of Beams and Girders; Special Cases of Beams and Girders Loaded and Supported in Different Ways; Stresses in Blocks and Columns; Types of Trusses; Stresses in Simple Bridge Trusses for Uniform Loads; Stresses in Railway Bridges from Wheel Loads; Stresses in Bridges from Horizontal Forces. There is an index of fourteen pages.

AMERICAN ELECTRIC RAILWAY PRACTICE.

By Albert B. Herrick and Edward C. Boynton. Cloth, 9½ x 6½ in., illus., 5 + 403 pp. New York, McGraw Publishing Company, 1907. $3.00 net.

Practical information relating to the construction, operation, and maintenance of the present-day American electric railway is to be found in this volume. Some of the subject-matter has already appeared in the *Street Railway Journal*, but the remainder has been gathered from the personal experiences of the authors in the various departments of the steam and electric railway transportation business. It is stated that the up-to-date methods of conducting the work

of the different departments of many of the most advanced roads are explained and illustrated, together with the apparatus used by such roads. All methods that have become obsolete have been omitted. The object has been not to advocate certain methods of management, etc., but rather to describe such as have been adopted with success in different localities. The book also includes many of the modern methods used in steam railway operation. The chapter headings are: Preliminary Estimates; Field Engineering for Interurban Roads; Railway Track Construction; Location of Power Station; Overhead Circuit, Time Tables and Schedules; Train Despatching and Signals; Rolling Stock; The Design of a Modern Car House; The General Design of a Modern Repair Shop; Maintenance of Interurban Track; Overhead Line Maintenance; The Operation of the Main Repair Shop; Maintenance of Equipment; Miscellaneous Subjects. There is an index of five pages.

SPECIFICATIONS FOR STREET ROADWAY PAVEMENTS.

By S. Whinery, M. Am. Soc. C. E. Paper, 9 x 6 in., 56 pp. New York, The Engineering News Publishing Company, 1907. 50 cents net.

This set of specifications for standard street pavements, embodying as it does the latest approved practice, is offered by the author to city engineers and municipal authorities as an aid in preparing specifications for any particular project. In order to make the specifications more useful numerous foot notes have been added, which refer to alternative requirements and methods of construction, and give reasons for the preference and adoption of the construction called for in the specification. No attempt has been made to submit specifications for proprietary or patented pavements, or for those composed wholly or in part of materials which are patented or protected by trademarks. A proposed form for a general specification for experimental or untried pavements will be found at the end of the pamphlet. The author states that he has aimed to make these specifications fair and just to the contractor, and that he has included many details which, from his own experience, he has found essential to the production of high-class work. The Contents are: Introductory; General Description and Provisions; Foundations; Concrete, Old Paving Stone, Broken Stone; Bituminous Pavements; Asphalt; Rock Asphalt, Block Asphalt; Granite, Brick and Wood-Block Pavements; General, Relating to All Pavements; Payments; Specifications for Experimental or Untried Pavements.

ELECTRIC LIGHT WIRING.

By C. E. Knox. Cloth, 9½ x 6 in., illus., 5 + 219 pp. New York, McGraw Publishing Company, 1907. $2.00 net.

The subject of electric light wiring has been treated by the author in such a manner as to make it intelligible to persons having only a general knowledge of electricity without omitting any of the technical accuracy. It is stated that this volume is not a reprint of the National Electric Code, nor an amplification of the same, but that it contains data and information used by the author in his own practice, the greater portion of such data never having been published. Numerous practical examples are given in order to illustrate more clearly the methods of designing electric wiring equipments. Sizes of lined and unlined conduits required for various-sized conductors are shown in Figs. 93 to 119 in the Appendix. The Contents are: Systems of Wiring; Methods of Wiring; Conductors; Fuses and Safety Devices; Cut-Out Panels and Cabinets; Outlet Boxes, Outlet Insulators, etc.; Feeders and Mains; Testing of Insulation Resistance, etc.; Wire Calculations; Alternating-Current Wiring; Calculation of Alternating-Current Circuits; Examples; Overhead Line Work; Underground Line Work; Appendix.

RAILWAY ORGANIZATION AND WORKING.

A Series of Lectures Delivered Before the Railway Classes of the University of Chicago. Edited by Ernest Ritson Dewsnup. Cloth, 8 x 5 in., illus., 11 + 498 pp. Chicago, The University of Chicago Press, 1906. $2.00 net.

During the past two years the University of Chicago, in co-operation with a number of railway officials, has conducted courses bearing upon the traffic, auditing, operating and other questions of railway organization. This volume

is a compilation of the special lectures delivered before these classes by prominent men connected with the various railways, each of whom describes and discusses the work of his own particular department in a practical and non-technical manner. The Contents include chapters on "The Work of the Law Department of a Railroad Company," by Blewett Lee, General Attorney, Illinois Central Railroad; "The Passenger Department," by Percy S. Eustis, Passenger Traffic Manager, Chicago, Burlington & Quincy Railroad; "Railroad Advertising," by Charles S. Young, in Charge of Advertising, Chicago, Milwaukee & St. Paul Railway, etc. In the Appendix a few papers by students are given, which are descriptive of points connected with the freight service. There is an index of seven pages.

THE BACTERIOLOGICAL EXAMINATION OF WATER SUPPLIES.

By William G. Savage. Cloth, 8 x 5 in., illus., 16 + 297 pp. Philadelphia, P. Blakiston's Son & Co., 1906. $2.50 net.

The bacteriological examination of water is stated to be the most valuable of all available methods by which to judge of the purity of a water supply. It has been the author's intention, in this book, to demonstrate only the established facts as to this particular method of water purification, and to bring the varied data, upon which it is based, into ordered relationship. He has, therefore, treated the subject from a critical standpoint, and has drawn only those practical conclusions which seem justified by the available evidence. The results of some of the investigations embodied in the book have appeared in various scientific journals, but many are new. There is an appendix in which a summary of procedure is recommended for the bacteriological examination of a sample of water. This is said to be liable to modification according to the water-supply examined, but is suited to most cases. There is also a lengthy bibliography of recent articles and books on the subject. The Chapter headings are: Influences Affecting Bacteria in Water; The Quantitative Bacterial Content of Natural Waters; Bacteriology of Excreta and Sewage in Relation to the Bacteriological Examination of Water; Soil in Relation to the Bacteriological Examination of Water; *Bacillus Coli* and Allied Organisms; The Eberth or Typhoid Group; Other Intestinal Bacteria; The Content of Various Waters with Regard to the Presence of *B. Coli, B. Enteritidis Sporogenes,* and Streptococci; Bacterial Indicators of Pollution; Interpretation of Results in the Bacteriological Examination of Water; Classification of Bacteria Found in Water; Collection and Transmission of Samples; General Quantitative Examination; Methods for the Enumeration and Identification of *B. Coli* and Allied Organisms; The Examination of Water for the Typhoid Bacillus; The Examination of Water for Other Intestinal Organisms. There is an index of five pages.

THE PREVENTION OF ACCIDENTS.

By F. W. Johnson. Ed. 2. Paper, 8½ x 6 in., 37 pp. New York, McGraw Publishing Company, 1907. 25 cents net.

This pamphlet consists of suggestions to the employees of street railway companies generally, concerning practical means of preventing the more common classes of accidents and as to the proper handling of such accidents when they do occur. There are short discussions of the following topics: The Accident; The Accident Report; Witnesses to Accidents; Courteous Treatment; The Prevention of Accidents; Rear-End Collisions of Cars; Collisions with Teams; etc.

THE ELEMENTS OF MECHANICS.

By W. S. Franklin and Barry Macnutt. Cloth, 9 x 6 in., illus., 11 + 283 pp. New York, The Macmillan Company, 1907. $1.50 net.

In a secondary title, the authors state that this book is intended for use as a textbook for colleges and technical schools. The first three chapters are devoted to introductory matter which the authors consider essential to the study of the chapters which follow. The remaining chapters are discussions on elementary mechanics, with a final chapter on Wave Motion and Oscillatory Motion. There are numerous explanatory notes scattered through the text, and at the end of each chapter there are problems to be worked out by the student. The Contents are: Introduction; The Measurement of Length, Angle, Mass and Time; Physical Arithmetic; Simple Statics; Translatory Motion; Friction, Work and Energy; Rotatory Motion; Elasticity (Statics); Hydrostatics; Hydraulics; Wave Motion and Oscillatory Motion. There is an index of five pages.

AMERICAN STREET RAILWAY INVESTMENTS, 1907.

Published Annually by the Publishers of the *Street Railway Journal,* for the Use of Bankers, Brokers, Capitalists, Investors, and Street and Interurban Railway Companies. Cloth, 13 x 10 in., illus., 54 + 453 pp. New York, The McGraw Publishing Company, 1907. $5.00.

This publication, of which this volume is the fourteenth annual edition, is issued in connection with the *Street Railway Journal.* It contains 453 pages of statistical matter, an increase of 21 pages over the edition of 1906. It covers the street railway companies in the United States, Canada, West Indies, Hawaii and the Philippine Islands. The names of the companies are arranged alphabetically under State and city, a short history of each road being given, with its capital stock, funded debt, plant, and the names and addresses of its officers, together with those of the general offices, power stations and repair shops. At the end of each report the date on which such information was obtained is given. There are 44 maps in the volume, on which the systems of 47 separate companies are shown, and an index to the street railway companies is also included.

ALLOWABLE PRESSURES ON DEEP FOUNDATIONS.

By Elmer Lawrence Corthell, M. Am. Soc. C. E. Cloth, 9 x 6 in., illus., 98 pp. New York, John Wiley & Sons, 1907. $1.25 net.

In 1902 the Argentine Government appointed a Board—of which the author was Chairman—to examine and report upon propositions for the construction of a port at the City of Rozario, on the Paraná River. A discussion of the question of the allowable pressure upon the material composing the bed of the river disclosed such a wide difference of opinion among the experts that the author decided to make a thorough investigation of the subject. The work was put into the hands of Charles R. Wyckoff, Jr., Jun. Am. Soc. C. E., and a circular letter was addressed to engineers in various countries, asking for information and data, either from their own, or from the experiences of others, in such work. The results were presented first in the form of a paper read before the Institution of Civil Engineers, and this volume is an elaboration of the paper. Only thirty replies of any value were received in answer to the circular letters sent out, but the tables in Appendix A give data of 178 examples of pressure on foundations. These tables are subdivided so that a short description is given of each example. Appendix B contains abstracts from reports upon pressures and friction. Appendices C and D are composed of personal statements and abstracts of published works, together with a bibliography of subject compiled by Mr. Wyckoff. A brief analysis of the tables is given by the author showing the safe pressures on various classes of materials such as fine sand, coarse sand and gravel, sand and clay, alluvium and silt, hard clay and hardpan.

BARRAGES EN MAÇONNERIE ET MURS DE RÉSERVOIRS.

Par Henri Bellet. Paper, 10 x 6 in., illus., 13 + 335 pp. Grenoble, A. Gratier & Jules Rey, 1907. 8 francs.

The author has divided his book into four parts. The first part is devoted to an elementary study of the subject, such as rules for calculating the thrust and normal pressures developed in dams of simple profile. Short descriptions of the principal methods of constructing dams, earth embankments, dams composed of several materials, of reinforced concrete, and of masonry are also given. The historical study of dams is taken up in the second part. The author shows the successive phases through which dam construction has passed, from the methods of M. de Sazilly to those of M. Maurice Lévy. The mathematical study of the subject is discussed in the third part. In the fourth part, the author describes a number of high dams constructed in France and other countries; together with new methods for the calculations for, and the construction of, modern dams. The appendices contain abstracts from the laws which govern the construction of dams in France, and these are followed by a short bibliography. The Contents are: Considérations Générales: Calculs Elémentaires de Stabilité; Divers Modes de Construction des Barrages. Etude Historique des Barrages: Barrages Anciens; Profils d'Egale Résistance de M. Delocre; Méthode de M. Bouvier; Etude de la Stabilité Suivant des Joints Obliques; Méthode de M. Maurice Levy; Barrages avec Puits. Théorie du Barrage: Etude des Actions Moléculaires Developpées dans un Barrage

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Webster, G. S. 1 bound vol.
Wells, F. D. 1 bound vol.
West Virginia-Dept. of Mines. 1 bound vol.
West Virginia-Geol. Survey. 1 bound vol., 8 maps.
Western Soc. of Engrs. 1 pam.
Wis.-Geol. and Natural History Survey. 1 bound vol.
Woburn, Mass.-City Government. 1 vol.
Woolson, I. H. 1 pam.
Wyoming-State Geologist. 1 pam.
Yonkers, N. Y.-Water Commrs. 1 pam.

BY PURCHASE.

Die Verunreinigung der Gewässer deren Schädliche Folgen sowie die Reinigung von Trink- und Schmutzwasser. Von J. König. 2 Vol. Berlin, Julius Springer, 1899.

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Engineering Work in Towns and Small Cities. By Ernest McCullough. Chicago, Technical Book Agency, 1906.

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Report of the Royal Commission of Great Britain on Metropolitan Sewage Discharge. 4 Vol. First Report, Second and Final Report, Minutes of Evidence taken before the Commission, from July, 1882, to October, 1884, together with a Selection from the Appendices and a Digest of the Evidence, Pts. I-II. London, Eyre and Spottiswoode, 1884-85.

Transactions of the Sanitary Institute of Great Britain. Vol. 3-18. London, Sanitary Institute, 1882-98.

Der Eisenbahnbau. Handbuch der Ingenieurwissenschaften. IV. Band. Erste Abteilung. Herausgegeben von F. Loewe und H. Zimmermann. Leipzig, Wilhelm Engelmann, 1907.

The Steam-Engine and Other Heat-Motors. By W. H. P. Creighton. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1907.

Sewage and the Bacterial Purification of Sewage. By Samuel Rideal. Third Edition. London, The Sanitary Publishing Co., Ltd.; New York, John Wiley & Sons, 1906.

Locomotives: Simple, Compound and Electric. By H. C. Reagan. Fifth Edition, Revised and Enlarged, New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1907.

Brooklyn Daily Eagle Almanac, 1907. Brooklyn, Brooklyn Daily Eagle.

Electric Railway Engineering. By H. F. Parshall and H. M. Hobart. New York, D. Van Nostrand Company, 1907.

Mine Timbering. By Wilbur E. Sanders, Bernard MacDonald, Norman W. Parlee and others. New York and London, Hill Publishing Company, 1907.

The Principles of Copper Smelting. By Edward Dyer Peters. New York and London, Hill Publishing Company, 1907.

The Common Bacterial Infections of the Digestive Tract and the Intoxications Arising from Them. By C. A. Herter. New York, The Macmillan Company; London, Macmillan & Co., Ltd., 1907.

Moody's Manual of Railroads and Corporation Securities, 1907. New York, The Moody Corporation; London, Fredc. C. Matheson & Sons; Amsterdam, J. H. De Bussy.

A Treatise on the Mathematical Theory of Elasticity. By A. E. H. Love. Second Edition. New York, G. E. Stechert & Co.; Cambridge, University Press, 1906.

The Fire at the Iroquois Theatre, Chicago, 30th December, 1903. London, The British Fire Prevention Committee, 1904.

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List of Members, 1907, Permanent International Assoc. of Navigation Congresses. Brussels, Imprimerie des Travaux Publics (Société Anonyme), 1907.

Report of Proceedings, Xth. International Navigation Congress, Milan, 1905. Milan, Organizing Committee of the Congress, Secretarial Department, 1906.

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Zoölogie Appliquée en France et aux Colonies. Par Jacques Pellegrin. Bibliothèque du Conducteur de Travaux Publics. Paris, H. Dunod et E. Pinat, 1907.

SUMMARY OF ACCESSIONS.

From May 7th to August 7th, 1907.

Donations (including 120 duplicates)	736
By purchase	46
Total	782

MEMBERSHIP.

ADDITIONS.

(May 8th to August 9th, 1907.)

MEMBERS.		Date of Membership.
BOWER, CHARLES PHILLIP. Engr., E. E. Smith Contr. Co., 709 Arcade Bldg., Philadelphia, Pa		June 5, 1907
BRADLEY, FRANK EDWARD. City Engr., New Rochelle, N. Y		Feb. 6, 1907
BRIGGS, WALDO CLAYTON. Care, Degnon Contr. Co., 60 Wall St., New York City		July 10, 1907
CHASE, MARVIN. Secy., Wenatchee Canal Co., Wenatchee, Wash.		June 5, 1907
CODE, WILLIAM HENRY. Chf. Engr., U. S. Indian Service, 522 Bumiller Bldg., Los Angeles, Cal		June 5, 1907
COLLIER, BYRAN CHEVES. Asst. Engr., Bureau of Highways, Bronx, 2721 Bainbridge Ave., Bronx, New York City	Assoc. M. M.	Oct. 3, 1900 June 4, 1907
CORNER, CHARLES. Res. Engr., Rhodesia Rys. (Northern Extensions), Box 422, Bulawayo, Rhodesia, South Africa	Assoc. M. M.	May 1, 1895 Mar. 5, 1907
CROSBY, WALTER WILSON. Johns Hopkins Univ., Baltimore, Md		July 10, 1907
DAGGETT, HERBERT CHAPIN. 176 Federal St., Boston, Mass.		July 10, 1907
DEVELIN, RICHARD GRIFFITH. Room 360, Broad St. Station, Philadelphia, Pa		May 1, 1907
DIMMICK, JOHN BAGLEY. U. S. Asst. Engr., 321 Lehigh Ave., Pittsburg, Pa		July 10, 1907
EVANS, EDWIN GEORGE. Hampton, N. B., Canada		July 10, 1907
FAUNTLEROY, JAMES DEARING. Laguna Dam, Yuma, Ariz.		June 5, 1907
GAUT, ROBERT EUGENE. Engr. of Bridges, Ill. Cent. R. R., 6415 Minerva Ave., Chicago, Ill		April 3, 1907
GIFFORD, ROBERT LADD. Pres., Illinois Eng. Co., 1210 Manhattan Bldg., Chicago, Ill.	Assoc. M. M.	May 6, 1903 June 4, 1907
GROSSART, LEWIS JOHN HENRY. 423 Commonwealth Bldg., Allentown, Pa		May 1, 1907
HALL, JOHN LINCOLN. 78 Fifth Ave., New York City		July 10, 1907
HAMILTON, JOHN WILSON. 29 Broadway, New York City.		July 10, 1907
HARA AIYAR, NARAYANA PRANATARTI. Local Fund Engr., Anantapoor Dist., Madras Presidency, India		Dec. 5, 1906
HARPER, JOHN LYELL. Chf. Engr., Niagara Falls Hydr. Power & Mfg. Co., Niagara Falls, N. Y		June 5, 1907
HEDGES, SAMUEL HAMILTON. 95 Yesler Way, Seattle, Wash.		July 10, 1907

MEMBERS (*Continued*).		Date of Membership.
HELDT, HANS LUDWIG. Supt., The Sombrerete Min. Co., Sombrerete, Zac., Mexico		June 5, 1907
HILL, ERNEST ROWLAND. 10 Bridge St., New York City.		July 10, 1907
HOBBY, ARTHUR STANLEY. P. O. Box 886, Havana, Cuba	Assoc. M. M.	Sept. 4, 1901 June 4, 1907
HOWE, GEORGE EDWARD. Engr. in Chg. of Constr., Water Purification Works, Board of Public Service, Columbus, Ohio	Assoc. M. M.	Mar. 4, 1903 April 30, 1907
HUSS, GEORGE MOREHOUSE. Chf. Engr., Big Fork & International Falls Ry. Co., Big Falls, Minn		May 1, 1907
JERVEY, HENRY. U. S. Engr. Office, Mobile, Ala		June 5, 1907
JONES, ARTHUR LEWIS. Box 423, Ogden, Utah		July 10, 1907
KETCHUM, RICHARD BIRD. Chf. Engr., Independent Coal & Coke Co., Helper, Utah		June 5, 1907
KNOX, SAMUEL LIPPINCOTT GRISWOLD. 324 Prospect Ave., Milwaukee, Wis		July 10, 1907
LAYFIELD, ELWOOD NORMAN. Chf. Engr., Chic. Terminal Transfer R. R., 353 Grand Central Passenger Station, Chicago, Ill		June 5, 1907
LEGARÉ, BALIE PEYTON. Care, United Railroads of San Francisco, San Francisco, Cal		July 10, 1907
LEWIS, MARCUS WINFIELD. 300 West 4th St., Superior, Wis.		June 5, 1907
MACKAY, HENRY MARTYN. Associate Prof. of Civ. Eng., McGill Univ., Montreal, Que., Canada		July 10, 1907
MARROQUIN Y RIVERA, MANUEL. Chf. Engr., New Water Supply, Calle Sur 38, No. 214, City of Mexico, Mexico		June 5, 1907
MATHEWSON, THOMAS KNIGHT. Angamacutiro, Michoacan *via* Penjamo, Mexico		May 1, 1907
MOGENSEN, PETER. 508 Columbia Bldg., Spokane, Wash.		July 10, 1907
MORITZ, CHARLES HOLLAND. Gen. Supt., Niagara Works of Aluminum Co. of America, Niagara Falls, N. Y.	Assoc. M. M.	Oct. 2, 1901 April 2, 1907
MURTAUGH, MARK MAURICE. Cons., Hydr. and Constr. Engr., Kenyon Hotel, Salt Lake City, Utah		May 1, 1907
PUGA, GUILLERMO BELTRAN Y. Direccion de Obras Publicas, City of Mexico, D. F., Mexico		June 5, 1907
REIMER, WILLIAM HENRI VALE. 28 N. Maple Ave., East Orange, N. J.		Mar. 6, 1907
SCHWITZER, JOHN EDWARD. Asst. Chf. Engr., Lines West of Port Arthur, Canadian Pac. Ry. Co., Winnipeg, Man., Canada		July 10, 1907
SHERBERD, JOHN MAXWELL. 122 North 2d St., Easton, Pa.		July 10, 1907

MEMBERS (*Continued*).

		Date of Membership.
SINKS, FRANK FORREST. Vice-Pres. and Secy., Condron & Sinks Co., 1442 The Monadnock, Chicago, Ill	Assoc. M.	May 2, 1906
	M.	June 4, 1907
SLIFER, HIRAM JOSEPH. Room 1407, Wall St. Exchange Bldg., New York City		June 5, 1907
SNELL, THOMAS CULLEN BRYANT. 903 N. Y. Life Bldg., Minneapolis, Minn		July 10, 1907
SPROUL, ARCHIBALD ALEXANDER. 142 Smith St., Peekskill, N. Y		May 1, 1907
TABOR, ERNEST FREDERICK. Engr., U. S. Reclamation Service, Corbett, Wyo		May 1, 1907
TAYLOR, WILLIAM GAVIN. 301 North Willow St., Waterbury, Conn		June 5, 1907
WESTON, GEORGE. 181 La Salle St., Chicago, Ill		June 5, 1907
WOOD, HENRY SHOTWELL. Room 839, Park Row Bldg., New York City		May 1, 1907
WOOD, WARREN POWELL. P. O. Box 38, Lewiston, Idaho.		July 10, 1907

ASSOCIATE MEMBERS.

ANDERSON, WILLIAM TOWNSEND. Supt. of Constr., Turner Constr. Co., 54 West 82d St., New York City		June 5, 1907
ARMSTRONG, ROBERT STUART. Chf. Engr., Brooklyn Plant, Empire Bridge Co., Ft. of Clay St., Brooklyn, N. Y.		Feb. 6, 1907
ASH, LOUIS RUSSELL. 309 Keith & Perry Bldg., Kansas City, Mo		Dec. 5, 1906
ATWOOD, WILLIAM GREENE. 54 L. S. & M. S. Bldg., Cleveland, Ohio		July 10, 1907
BLIEM, DANIEL WILLIAM. Mgr., Berlin Plant, Am. Bridge Co., East Berlin, Conn		June 5, 1907
BOWDITCH, JOHN HENRY. Asst. Engr., Staten Island Rapid Transit Ry. Co., New Brighton, N. Y		July 10, 1907
BRIGGS, HARRY ALSON. Engr. with MacArthur Bros. Co., Katonah, N. Y		May 1, 1907
BRODIE, ORRIN LAWRENCE. Care, Board of Water Supply, 299 Broadway, New York City		July 10, 1907
BROWN, NORMAN FREED. Asst. Engr. of Constr., P. R. R., 427 Atlantic Ave., Pittsburg, Pa		June 5, 1907
BUNNEL, WILLIAM CYRUS. Junior Engr., U. S. Engr. Office, Box 155, Manila, Philippine Islands	Jun.	Oct. 1, 1901
	Assoc. M.	Jan. 2, 1907
CLARKE, WILLIAM DEXTER. Milford, Lassen Co., Cal		July 10, 1907
COLLINS, GEORGE JAMES SCHILLING. Designing and Constr. Engr., 616 Bee Bldg., Omaha, Nebr		June 5, 1907

ASSOCIATE MEMBERS (*Continued*).

	Date of Membership.
CURTIS, LOREN BRADLEY. 503 Commonwealth Bldg., Denver, Colo	July 10, 1907
DAGGETT, FRED WALLIS. 287 Mill St., Poughkeepsie, N. Y	May 1, 1907
DARROW, FRANK TENNEY. 2026 A St., Lincoln, Nebr	May 1, 1907
DEACON, ERNEST FRANKLIN. Res. Engr., S. & W. Ry., Altapass, N. C	July 10, 1907
DEVLIN, HENRY STRATFORD. 357a Clinton St., Brooklyn, N. Y	June 5, 1907
DONALD, ROBERT L'AMY. Failing Bldg., Portland, Ore	May 1, 1907
DORSEY, WILLIAM HENRY. Engr. and Mgr., Sanford & Brooks Co., 24 Commerce St., Baltimore, Md	June 5, 1907
EASTERBROOKS, PRESTON BURT. Care, Westinghouse, Church, Kerr & Co., 10 Bridge St., New York City.	May 1, 1907
EVERHAM, ARTHUR CASSIDY. Terminal Engr., Detroit River Tunnel Co., M. C. Depot, Detroit, Mich. — Jun.	Feb. 6, 1906
— Assoc. M.	June 5, 1907
FENN, ROBERT WILLSON. Agt., Union Oil Co. of California, Apartado 288, Panama, Panama	July 10, 1907
FIRTH, JOSEPH. Box 290, Charleston, W. Va	June 5, 1907
FISK, CLINTON HINCKLEY. Chf. Engr., Baton Rouge, Hammond & Eastern R. R., 5512 Chestnut St., New Orleans, La	June 5, 1907
FORBES, MURRAY. Greensburg, Pa	June 5, 1907
FOWLER, FRANK GEORGE. Mount Kisco, N. Y	June 5, 1907
FRICKSTAD, WALTER NETTLETON. Instr. in Civ. Eng., Univ. of California, Berkeley, Cal	June 5, 1907
FRISELL, ERIC HJALMAR. Care, Milliken Bros., Apartado 1244, City of Mexico, Mexico	June 5, 1907
GRAY, EDWARD. Engr., M. of W., Southern Ry. Co., 623 Chemical Bldg., St. Louis, Mo	May 1, 1907
GREEN, PAUL EVANS. 315 Giddings St., Chicago, Ill	July 10, 1907
GREGORY, ALFRED COOKMAN. 555 Rutherford Ave., Trenton, N. J	June 5, 1907
GUDE, ALBERT VALDEMAR, JR. Prudential Bldg., Atlanta, Ga.	June 5, 1907
GUSTAFSON, GUSTAF EDWARD. 974 Cuyler Ave., Chicago, Ill.	July 10, 1907
GUSTIN, R. PROSPER. 707 St. Johns Pl., Brooklyn, N. Y.	May 1, 1907
HARRIS, GUY WALTER. 2d and Grant Sts., Amarillo, Tex.	June 5, 1907
HORTON, ALBERT HOWARD. Dist. Hydrography, U. S. Geological Survey, 1330 F St., Washington, D. C. — Jun.	June 3, 1902
— Assoc. M.	Mar. 6, 1907
HOWALT, WILHELM JENS CHRISTIAN. Ridgway, Pa	June 5, 1907
JAHNCKE, ERNEST LEE. 814 Howard Ave., New Orleans, La.	July 10, 1907

ASSOCIATE MEMBERS (*Continued*).

		Date of Membership.
KAUFFMAN, VERNET ALBERT. Asst. Engr., Ferrocarril Rio Grande, Sierra Madre y Pacifico, Nuevo Casas Grandes, Chih., Mexico	Jun.	Feb. 3, 1903
	Assoc. M.	July 10, 1907
LANCASHIRE, FOREST HENRY. Apartado 224, Monterey, N. L., Mexico		July 10, 1907
LEE, JOHN LOUIS. East Providence, R. I.		April 3, 1907
LINARD, DREW JONES. Care, American Consulate, Ceiba, Honduras		July 10, 1907
MCGEEHAN, PAUL. Boone, Iowa		July 10, 1907
MAIER, HARRY LUDWIG. Asst. Engr., Street and Sewer Dept., 229 Connell St., Wilmington, Del		June 5, 1907
MAPES, CHARLES MAYNARD. Smith Bldg., 148th St. and Third Ave., New York City		July 10, 1907
MEGGY, ROBERT LOUIS GURDELSTON. Parksville, Edgefield Co., S. C.		Feb. 6, 1907
MÓLLER, LOUIS. 130 Lafayette Ave., Detroit, Mich		May 1, 1907
MOORSHEAD, ALFRED LEE. 67 Laurel Ave., Arlington, N. J.		April 3, 1907
MORSSEN, CHARLES MICHAEL. Care, Hennebique Constr. Co., 1170 Broadway, N. Y. City		June 5, 1907
NEWBEGIN, PARKER CLEAVELAND. Maintenance Engr., Bangor & Aroostook R. R., Houlton, Me		May 1, 1907
OAKES, JOHN CALVIN. Capt., Corps of Engrs., U. S. A., Galveston, Tex		May 1, 1907
ORTIZ, EDUARDO. Coliseo Viejo No. 6, City of Mexico, Mexico	Jun.	Nov. 4, 1902
	Assoc. M.	May 1, 1907
PALMER, MARSHALL BARKER. Res. Engr., New York State Barge Canal, Rome, N. Y.		June 5, 1907
PARKER, PHILIP A MORLEY. Care, Irrigation Secretariat, Lahore, Punjab, India		Mar. 6, 1907
PARSONS, HAROLD ASHTON. Stamford, Conn		May 1, 1907
PEASE, FREDERICK ATWOOD. Williamson Bldg., Cleveland, Ohio		June 5, 1907
PETERSEN, CHARLES WALTER. Chf. Draftsman, C., R. I. & P. Ry., 802 La Salle St. Station, Chicago, Ill.		Feb. 6, 1907
PFLUEGER, ALVIN CYRUS. Asst. Engr., Penn., N. Y. & L. I. R. R., 225 West 33d St., New York City		June 5, 1907
POOLE, CHARLES ARTHUR. Barge Canal Office, DeGraaf Bldg., Albany, N. Y.		June 5, 1907
RASTER, WALTHER. With E. C. & R. M. Shankland, 1106 The Rookery, Chicago, Ill	Jun.	Feb. 4, 1902
	Assoc. M.	Mar. 6, 1907
REED, ALFRED CLARE. Chf. Engr., The Spanish American Iron Co., Mayari, Cuba		June 5, 1907

ASSOCIATE MEMBERS (*Continued*).

		Date of Membership.
REED, WILLIAM BELDEN, JR. Vice-Pres., White Plains Constr. Co., 133 Railroad Ave., White Plains, N. Y.	Jun.	Dec. 1, 1896
	Assoc. M.	June 5, 1907
REEL, CHARLES GORDON. Vice-Pres. and Gen. Mgr., Kingston Consolidated R. R. Co., 320 Broadway, Kingston, N. Y.		June 5, 1907
REICH, PHILLIP JACOB. Engr., Toledo Plant, Am. Bridge Co., Toledo, Ohio		June 5, 1907
REICHARDT, WALTER FREDERICK. Superv. Engr. of Bldgs., Southwestern Telegraph & Telephone Co., Little Rock, Ark.	Jun.	Jan. 31, 1905
	Assoc. M.	July 10, 1907
ROBBINS, FRANKLIN HENRY. Aspinwall, Pa		July 10, 1907
ROBINSON, HERBERT FULWILER. Phœnix, Ariz		July 10, 1907
RODENBOUGH, JAMES FOSTER. 571 West 139th St., New York City		April 3, 1907
RUE, MALCOLM ASHER. Structural Engr., Am. Bridge Co., 42 Broadway, New York City		June 5, 1907
SAPH, AUGUSTUS VALENTINE. 2226 D. Chapel, Berkeley, Cal.	Assoc.	Oct. 1, 1901
	Assoc. M.	June 4, 1907
SAUERMAN, HENRY BURGER. Coaling Station Engr., 643 East 66th St., Chicago, Ill		May 1, 1907
SAVAGE, JOHN LUCIAN. Engr., U. S. Reclamation Service, Boise, Idaho		May 1, 1907
SCHAEFFLER, JOSEPH CARL. Mech. and Civ. Engr., Tremont Bldg., Boston, Mass.	Jun.	Feb. 28, 1905
	Assoc. M.	June 5, 1907
SCHREIBER, JOHN MARTIN. 448 Summer Ave., Newark, N. J.		June 5, 1907
SCHUBERT, FREDERICK CELESTINE. 295 Lincoln St., Portland, Ore		June 5, 1907
SCHWARZE, CARL THEODORE. 490 Tenth St., Brooklyn, N. Y.		May 1, 1907
SMITH, EDGAR FIELD. 318 West 126th St., New York City		May 1, 1907
SMITH, LAYTON FONTAINE. Res. Engr. Mgr., Trussed Concrete Steel Co., Wilson Bldg., Baltimore, Md.		June 5, 1907
SPRAGUE, NORMAN SALISBURY. Supt., Bureau of Constr., City Hall, Pittsburg, Pa		July 10, 1907
STEPATH, CHARLES UNDERHILL. 154 West 122d St., New York City	Jun.	Feb. 3, 1903
	Assoc. M.	July 10, 1907
STEPHENSON, STUART AUGUSTUS, JR. Asst. Engr., J. G. White & Co., Inc., Caguas, Porto Rico (Res., 77 Maple Ave., New Rochelle, N. Y.)	Jun.	Jan. 3, 1905
	Assoc. M.	July 10, 1907
TILLINGHAST, FREDERICK HOWARD. Care, U. S. Reclamation Service, Belle Fourche, S. Dak		May 1, 1907

ASSOCIATE MEMBERS (*Continued*).

	Date of Membership.
TUDOR, CLINTON GAMBRILL. P. O. Box 862, Reno, Nev..	May 1, 1907
UNDERHILL, GRANDISON GRIDLEY. Barge Canal Office, Albany, N. Y.	June 5, 1907
VEHRENKAMP, HENRY WILLIAM. Chf. Engr., The Ferro Concrete Constr. Co., 521 Milton St., Cincinnati, Ohio	June 5, 1907
WAUGH, WILLIAM HAMMOND. Chf. Engr., Shenango Traction Co., Greenville, Pa.	Jun. Oct. 1, 1901 Assoc. M. June 5, 1907
WEIDEL, JOSEPH. 1111 Arizona Ave., Trinidad, Colo...	July 10, 1907
WILLIAMS, HOWARD SHAY. 6514 Euclid Ave., Cleveland, Ohio	Jun. Dec. 1, 1903 Assoc. M. June 5, 1907
WILLIS, HARRY PARSONS. Waterford, Saratoga Co., N. Y..	Mar. 6, 1907
WOOD, GEORGE. 150 Union St., High Bridge, New York City	June 5, 1907
WORLEY, JOHN STEPHEN. 613 Nasby Bldg., Toledo, Ohio.	June 5, 1907

ASSOCIATES.

EGLEE, CHARLES HENRY. Gen. Mgr., Ambursen Hydr. Constr. Co., 176 Federal St., Boston, Mass	July 10, 1907
FERRIS, JAMES JOSEPH. 26 Exchange Pl., Jersey City, N. J.	July 10, 1907
GREEN, FREDERICK WILLIAM. Gen. Supt., L. & A. Ry. Co., Stamps, Ark.	May 1, 1907
MORE, CHARLES CHURCH. Bridge Dept., C., M. & St. P. Ry. Co. of Wash.; address, Box 93, Washington Station, Seattle, Wash.	Jun. May 2, 1899 Assoc. Feb. 6, 1907
SMITH, CAMERON C. Pres. and Gen. Mgr., Union Steel Casting Co., Pittsburg, Pa.	June 5, 1907
VON SCHRENK, HERMANN. Pathologist, The Missouri Botanical Garden, St. Louis, Mo.	July 10, 1907

JUNIORS.

ACKERMAN, ALEXANDER SEYMOUR. Hotel Tivoli, Ancon, Canal Zone, Panama	April 30, 1907
ATWOOD, WILLIAM BARTLETT. R. F. D. No. 9, Lima, Ohio	April 30, 1907
BECKER, RUDOLPH CONRAD. Care, N. Y. Board of Water Supply, Lackawack, N. Y.	April 30, 1907
BELLOWS, DANIEL EVERETT. Little Falls, N. Y.	April 30, 1907
BENEDICT, FARRAND NORTHROP. 15 Fourth St., Long Island City, N. Y.	June 4, 1907
BUNKER, PAUL DELMONT. Key West Barracks, Fla.	June 4, 1907
BURKE, RALPH HANEY. Care, Sanitary Dist. of Chicago, Lockport, Ill.	Dec. 4, 1906

JUNIORS (*Continued*).

	Date of Membership.
BURNS, WALTER ELLIOTT. 2124 Bancroft Way, Berkeley, Cal.	Mar. 5, 1907
BURROUGHS, FREDERIC. Aspinwall, Pa.	June 4, 1907
CAHILL, JOHN RICHARD. 130 Broderick St., San Francisco, Cal.	April 30, 1907
DORRANCE, FRANK YOUNG. Box 349, Aspinwall, Pa.	Feb. 5, 1907
FINCH, JAMES KIP. 509 High St., Easton, Pa.	June 4, 1907
FOUNTAIN, THOMAS LILLY. 143 Liberty St., Room 631, New York City.	April 2, 1907
GOODMAN, HARRY MINOTT. 1412 Milvia St., Berkeley, Cal.	June 4, 1907
HALL, HUBERT HARRY. Dawson, Y. T., Canada.	April 30, 1907
HARPER, FREDERICK CLAYTON. Engr., Tacoma Eastern R. R., Tacoma, Wash.	April 30, 1907
HARVEY, MICHAEL SMITH. Ruby, Miss.	April 30, 1907
HATCH, FREDERICK NATHANIEL. Smelter, McGill, Nev.	June 4, 1907
HAWLEY, CHARLES RAY. Honey Grove, Tex.	Feb. 5, 1907
HAYES, RALPH DANIEL. 1 Highland Ave., Middletown, N. Y.	June 4, 1907
HUMPHREY, FREDERIC LEABOYD. Care, U. S. Reclamation Service, Las Cruces, N. Mex.	June 4, 1907
JONES, IRVING PAUL. Care, General Delivery, Portland, Ore.	Mar. 5, 1907
NIKIRK, FRANK AUSTIN. 60 W. Virginia St., San José, Cal.	April 2, 1907
O'BYRNE, LEO CHARLES. 996 Washington Blvd., Chicago, Ill.	Feb. 5, 1907
O'HEARN, JOHN LYNCH. Care, Union Constr. Co., Clinton, Okla.	Feb. 5. 1907
PARKER, JAMES LAFAYETTE. 116 Nassau St., Room 901, New York City.	April 2, 1907
PATTERSON, EARL. U. S. Reclamation Service, Trust Bldg., El Paso, Tex.	April 30, 1907
PLUMMER, HORACE EDWARDS. 507 Lumber Exchange, Portland, Ore.	April 30, 1907
RANNEY, CHARLES GARFIELD. Leveler, N. Y. State Eng. Dept., Mohawk, N. Y.	April 30, 1907
ROGERS, THOMAS FARWELL. 156 Nineteenth St., Pacific Grove, Cal.	Mar. 5, 1907
SISSON, GEORGE ARTHUR. P. O. Box 1007 (U. S Engr. Office), Manila, Philippine Islands.	April 30, 1907
VENSANO, HARRY CHITTENDEN. 1642 Fell St., San Francisco, Cal.	June 4, 1907
WALKER, EDWARD GEORGE. 50 Kingsfield Rd., Watford, Herts, England	April 2, 1907

JUNIORS (*Continued*).

	Date of Membership.
WILBANKS, JOHN ROBERT. 820 Security Bldg., St. Louis, Mo.	June 4, 1907
WILLIAMS, LEROY DUNCAN. Lock Box 59, Bevier, Mo.	Feb. 5, 1907
WILLIS, ALBERT JONES. 722 Cherokee St., South Bethlehem, Pa.	June 4, 1907
WOOD, ROBERT WALTER. 26 Post Ave., West New Brighton, N. Y.	April 30, 1907

CHANGES OF ADDRESS.

MEMBERS.

ADAMS, HENRY SEWALL. 108 Ames Bldg., Boston, Mass.

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BAKER, *Sir* BENJAMIN. Elected Honorary Member, May 5th, 1897; died May 19th, 1907.

BRODHEAD, CALVIN EASTON. Elected Member, February 21st, 1872; died April 29th, 1907.

FILLEY, HIEL HAMILTON. Elected Member, January 3d, 1883; died May 6th, 1907.

HASIE, MONTAGUE SYLVESTER. Elected Member, February 3d, 1897; died May 30th, 1907.

HASWELL, CHARLES HAYNES. Elected Member, January 29th, 1868; Honorary Member, May 12th, 1905; died May 12th, 1907.

HENRY, DANIEL FARRAND. Elected Member, July 7th, 1875; died May 13th, 1907.

HUTTON, NATHANIEL HENRY. Elected Member, June 3d, 1896; died May 8th, 1907.

POWELL, CHARLES FRANCIS. Elected Member, October 3d, 1888; died July 30th, 1907.

ROGERS, MERRITT HARRISON. Elected Member, January 2d, 1890; died May 3d, 1907.

ZIPPERLEIN, JOSEPH WILLIAM. Elected Associate, June 4th, 1901; died July 22d, 1907.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(May 6th to August 7th, 1907.)

NOTE.—*This list is published for the purpose of placing before the members of the Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(1) *Journal*, Assoc. Eng. Soc., 31 Milk St., Boston, Mass., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Blk., Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.

(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 803 Fulton Bldg., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne, England.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Industrial World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(70) *Engineering Review*, New York City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.
(72) *Electric Railway Review*, Chicago, Ill., 10c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, Ill., 10c.
(77) *Journal*, Inst. Elec. Engrs., London, England.
(78) *Beton und Eisen*, Vienna, Austria.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie-Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Dinglers Polytechnisches Journal*, Berlin, Germany.
(83) *Progressive Age*, New York City, 15c.
(84) *Le Ciment*, Paris, France.
(85) *Proceedings*, Am. Ry. Eng. and M. of W. Assoc., Chicago, Ill.
(86) *Engineering World*, Chicago, Ill.
(87) *Roadmaster and Foreman*, Chicago, Ill., 10c.

LIST OF ARTICLES.

Bridge.

Influence Lines for Suspended Cantilevers.* Myron S. Falk. (6) Apr.
The Sandy Hill Bridge over the Hudson River; a Long Reinforced-Concrete Arch Bridge with Block Facing.* (13) May 9.
Smallheath Bridge, Birmingham.* (11) Serial beginning May 10.
The Oakland Bridge, Pittsburg, Pa.: A Steel Arch without Hinges.* Willis Whited, Assoc. M. Am. Soc. C. E. (13) May 16.
The Jacksonville Viaduct.* (14) May 18.
Special Bridge Structures for the Track Elevation of the Chicago, Burlington & Quincy Ry. in Chicago.* (14) May 18.
Moving Loads on Railway Under-Bridges.* H. Bamford. (11) May 31.
Detailed Cost of Erecting a Steel Bridge of 155 ft. Span. (87) June.
Cost of Erecting Two Steel Truss Bridges of 180 ft. Span, and One Plate Lattice Girder of 100 ft. Span. (87) June.
Detailed Cost of Erecting Three Plate Girder Bridges of Ten Spans. (87) June.
Cost of Erecting a Draw Bridge of 236 ft. Span. (87) June.
Progress of the Blackwell's Island Bridge Erection.* (14) June 8.
Page Single-Leaf Double Track Bascule Railroad Bridge over the Chicago River.* A. R. Ekstrom. (15) June 14.
An Extensometer for Recording Deformations in Bridge Members under Impact Stress.* (13) June 20.
The Piney Branch Concrete Arch Bridge at Washington, D. C.* (13) June 20.
The Quebec Bridge Superstructure Details.* (14) Serial beginning June 22.
A Six-Track Solid-Floor Plate-Girder Bridge.* (14) June 22.
The Widening of Blackfriars Bridge.* (11) June 28.
Falsework for the Pennsylvania R.R. Bridge Across the Susquehanna River at Havre de Grace, Md.* (87) July.
The Cost of a Coffer Dam and Concrete Pier on Pile Foundation.* (87) July.
Details of Derrick Car and Methods of Work Adopted for Erecting a Railway Bridge.* (87) July.
Cost of Erecting Three Steel Viaducts of 500 ft., 580 ft., 1 170 ft. Length, with Summaries of Costs of Labor and Materials and New Formula for Computing the Weight of Viaducts.* (87) July.
The Detailed Cost of a Pneumatic Caisson and Masonry Bridge Pier. (87) July.

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The Detailed Cost of Two Pneumatic Caissons and Masonry Bridge Piers. (87) July.
Bascule Bridge for the Corporation of Portsmouth.* (11) July 5.
Rall Bascule Bridge Over the Illinois River at Peoria.* (15) July 5; (18) July 13.
The Moodna Creek Viaduct, Erie R.R.* (14) July 6.
The Bridge over the River Wear at Sunderland.* (11) July 12.
Some New Bascule Bridges.* (13) *July 18.
New Bridge of Baltimore & Ohio at Havre de Grace, Md. (40) July 19.
Brush Creek Viaduct on the Alabama Western-Birmingham Extension of the Illinois Central.* (40) July 26.
Reinforced Concrete Abutments on the Atlanta, Birmingham & Atlantic R.R.* (14) July 27.
Removing a Stone Arch Bridge over the Northern Railway of France.* (13) Aug. 1.
Richland Creek Viaduct, Indianapolis Southern Railway. (14) Aug. 3.
Granite-Faced Concrete Bridge on the Boston & Worcester Street Railway.* (72) Aug. 3.
Calcul de Résistance et Mode d'Exécution Employé dans la Reconstruction du Pont du Guildo (Ligne de Plancoët à Saint-Cast).* Harel de la Noé. (43) 1907, Pt. II.
Glissement de Terrain au Viaduc du Gor (Espagne).* Arsène Portier. (32) Mar.
Pont à Transbordeur de Runcorn (Angleterre).* (35) Serial beginning May.
Pont Cantilever sur le Schwarzwassertobel (Suisse).* (33) June 1.
Pont Tournant à Deux Etages sur le Port Supérieur de Hambourg.* A. Bidault des Chaumes. (33) July 6.
Die Untersuchung des Elastischen Gewölbes. E. Elwitz. (49) Serial beginning Vol. 7-9, 1907.
Der Zweigelenkbogen mit Zugband in Beliebiger Höhe.* F. Bohny. (48) Serial beginning May 4.
Der Osske-Kühnesche Biegungszeichner und die Auswertung Seiner bei Eisenbahnbrücken Ermittelten Messungsergebnisse.* Jaehn. (82) May 4.
Die Strassenbrücke über den Rhein zwischen Ruhrort und Homberg.* W. Dietz. (48) Serial beginning May 11.
Projekt einer Eisenbetonbogenbrücke über die Rekka.* Felix Adutt. (53) May 24.
Schwimmende Brücke mit Schiffsdurchlass.* R. Weyland. (48) June 29.
Strassenbrücke II. Klasse aus Armiertem Beton.* Humbert Ehrlich. (78) July.
Die Eindeckung der Fabrikdächer in Eisenbeton.* L. Geusen. (78) Serial beginning July.
Ueber die Ermittlung der Eiseneinlagen in Gewölben.* Dr.-Ing. Kögler. (78) July.
Die Neue Eisenbahnbrücke über den Neckar bei Heidelberg.* G. Lucas, D. R. Müller and G. Trauer. (51) Serial beginning July 6.
Mitteilungen über Ergebnisse der Probebelastung durchgehender (kontinuierlicher), mit den Unterstützenden Trägern Zusammenhängender Eisenbetonplatten.* M. Koenen. (From a paper read before the Deutscher Beton-Verein.) (51) Serial beginning July 10.

Electrical.

Mechanical Considerations in the Design of High-Tension Switch-Gear.* Henry William Edward Le Fanu. (63) Vol. 168.
Notes on the Characteristic Curves of the Direct-Current Machine.* Harrison W. Smith. (7) Mar.
Recent Developments in Large Central Electric Plants. Thos. C. McBride. (2) Apr.
Direct Current Compensators for Balancing Electric Circuits.* H. M. Biebel. (4) Apr.
The Telephone Wire Plant.* Sergius P. Grace. (42) Apr.
Light from Gaseous Conductors within Glass Tubes; the Moore Light.* D. McFarlan Moore. (42) Apr.
Potential Stresses as Affected by Overhead Grounded Conductors.* R. P. Jackson. (42) Apr.
Protection Against Lightning, and the Multigap Lightning Arrester.* David B. Rushmore and D. DuBois. (42) Apr.
New Principles in the Design of Lightning Arresters.* E. E. F. Creighton. (42) Apr.
The Rowland Telegraphic System.* Louis M. Potts. (42) Apr.
Notes on Hydroelectric Plant Organization and Operation. Farley Osgood. (42) Apr.

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Forced-Oil and Forced-Water Circulation for Cooling Oil-Insulated Transformers.* C. C. Chesney. (42) Apr.

Relative Merits of Three-Phase and One-Phase Transformers. H. W. Tobey. (42) Apr.

Relative Advantages of One-Phase and Three-Phase Transformers. John S. Peck. (42) Apr.

New Incandescent Lamps.* J. Swinburne. (77) Apr.

Investigations on Light Standards and the Present Condition of the High-Voltage Glow Lamp.* Clifford C. Paterson. (77) Apr.

Comparative Life Tests on Carbon, Nernst, and Tantalum Incandescent Lamps Using Alternate Currents.* H. F. Haworth, T. H. Matthewman and D. H. Ogley. (77) Apr.

The Heating Coefficient of Magnet Coils.* G. A. Lister. (77) Apr.

Rotary Converters *versus* Motor-Generators.* Miles Walker. (77) Apr.

Some Power Transmission Economics.* Frank G. Baum. (42) May.

The Vector Diagram of the Compensated Single-Phase Alternating-Current Motor.* W. I. Slichter. (42) May.

Inductive Disturbances in Telephone Line.* Louis Cohen. (42) May.

The Properties of Electrons.* Samuel Sheldon. (42) May.

Choke-Coils Versus Extra Insulation on the End-Windings of Transformers. S. M. Kintner. (42) May.

Protection of the Internal Insulation of a Static Transformer against High-Frequency Strains.* Walter S. Moody. (42) May.

Transmission Line Towers and Economical Spans.* D. R. Scholes. (42) May.

Lightning-Rods and Grounded Cables as a Means of Protecting Transmission Lines against Lightning.* Norman Rowe. (42) May.

Location of Broken Insulators and other Transmission Line Troubles.* L. C. Nicholson. (42) May.

One-Phase High-Tension Power Transmission.* E. J. Young. (42) May.

Wind Power for the Generation of Electricity.* W. O. Horsnaill. (73) Serial beginning May 3.

The Kent Electric Power Company.* (73) Serial beginning May 10.

Steno-Telegraphy.* (73) May 10.

The Power Station of the Little Rock Railway & Electric Company.* (17) May 11.

Tyrol Hydro-Electric Power Station, Keiserwerke.* Franz Koester. (27) May 11.

Commutating Poles in Direct-Current Machinery.* (27) May 11.

Great Falls Station of the Southern Power Co.* (14) Serial beginning May 18.

The New Turbine Power Station of the Dallas Electric Corporation.* (17) May 18.

Combined Telegraph and Telephone System used by the Inter-Urban Railway, Des Moines.* E. R. Cunningham. (17) May 18.

Generating Station of the Merchants Electric Light, Heat & Power Company of York, Pa.* (27) May 18.

A Brief Theory of the Reduction in the Service Life of Frosted Incandescent Lamps.* A. E. Kennelly. (27) May 18.

Telegraph Switching: Metropolitan Intercommunication Scheme.* (26) Serial beginning May 24.

The Pupin Telephone Cable across Lake Constance.* (73) May 24.

Hydro-Electric Developments on the Catawba River, South Carolina.* (27) May 25.

Economical Conductor Section.* Frank G. Baum. (27) May 25.

Automatic Calling Device for a Wireless Telegraph Station.* W. R. Carroll. (27) May 25.

Recent Contributions to Electric Wave Telegraphy.* J. A. Fleming. (Paper read before the Royal Inst. of Great Britain.) (73) Serial beginning May 31; (11) May 31.

Recent Developments in Wireless Telegraphy. Lee De Forest. (3) June.

The Rotary Converter Sub-Station.* R. F. Schuchardt. (4) June.

The Development and Operation of a Large Electric Transmission and Conversion System.* Ernest F. Smith. (4) June.

The Heating of Copper Wires by Electric Currents.* A. E. Kennelly and E. R. Shepard. (42) June.

Interaction of Synchronous Machines.* Morgan Brooks. (42) June.

A New Type of Insulator for High-Tension Transmission Lines.* E. M. Hewlett. (42) June.

Some New Methods in High Tension Line Construction.* H. W. Buck. (42) June.

Switchboard Practice for Voltages of 60 000 and Upwards.* Stephen Q. Hayes. (42) June.

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Power-Factor, Alternating-Current Inductive Capacity, Chemical and Other Tests of Rubber-Covered Wires of Different Manufacturers.* Henry W. Fisher. (42) June.

Notes on Transformer Testing.* H. W. Tobey. (42) June.

A Proposed Lightning-Arrester Test.* N. J. Neall. (42) June.

Practical Testing of Commercial Lightning-Arresters.* Percy H. Thomas. (42) June.

Protective Apparatus Engineering.* E. E. F. Creighton. (42) June.

Three-Phase Electric Power Transmission at the Cape Explosive Works. R. S. Mansel. (Abstract). (77) June.

The Modern Theory of Electrical Conductivity of Metals. J. J. Thomson. (77) June.

The Transmission of Electrical Energy by Direct Current on the Series System.* J. S. Highfield. (77) June.

Magnetic Leakage and its Effect in Electrical Design. William Cramp. (77) June.

Modern Transformer Design.* H. Bohle (Abstract.) (77) June.

Generating Stations and Sub-Stations of the Potomac Electric Power Company, of Washington, D. C.* (27) June 1.

Electric Automobiles in Washington.* (27) June 1.

The Driving of Wood-Working Machines by Electricity.* (12) June 7.

On Recording Transitory Electrical Phenomena by the Oscillograph.* J. T. Morris. (73) June 7.

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Electricity in the Government Buildings in Washington.* (27) June 8.

The Mechanism of Power Transmission from Electric Motors.* Wilfrid L. Spence. (47) Serial beginning June 8.

Static Balancers.* Charles C. Garrard. (26) Serial beginning June 14.

The Variation of Manganin Resistances with Atmospheric Humidity.* E. B. Rosa and H. D. Babcock. (Paper read before the Amer. Physical Soc., Washington.) (73) June 14; (27) June 29.

Coal Handling and Condensing Equipment in the Gold Street Station of the Edison Electric Illuminating Company of Brooklyn.* (27) June 15.

The Frindsbury Plant of the Kent Electric Power Co.* (26) June 21.

Air Slipper Brakes.* (26) June 21.

Greenville-Carolina Power Company, Greenville, S. C.* J. S. Viehe. (27) June 22.

On the Determination of the Mean Horizontal Intensity of Incandescent Lamps.* Edward P. Hyde and F. E. Cady. (27) June 22.

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Storage Battery Developments in Train-Lighting Service.* C. R. Gilman. (40) June 28.

On the Loss of Energy in the Dielectric of Condensers and Cables. Bruno Monasch. (73) Serial beginning June 28.

The Taylor's Falls, Minn., Water-Power Development.* (14) Serial beginning June 29.

Recent Improvements in Motor and Control.* Clarence Renshaw. (Paper read before the St. Ry. Assoc. of N. Y.) (17) June 29.

Recent Improvements in Motor and Control. G. H. Hill. (Paper read before the St. Ry. Assoc. of N. Y.) (17) June 29.

Canadian Niagara Power Company's Transmission to Buffalo.* (27) June 29.

Elements Affecting the Accuracy of Induction Type Watt-Hour Meters.* H. W. Young. (27) June 29.

Georgetown Power Station of the Seattle Electric Company.* (72) June 29.

Aerial Cable Construction for Telephone Exchanges.* C. W. Burkett. (10) July.

Reactions between Compound-wound Generators Operating in Parallel.* Clarence A. Boddie. (64) July.

"Flexibles," with Notes on the Testing of Rubber.* Alfred Schwartz. (77) July.

Magnetic Oscillations in Alternators.* Gladstone W. Worrall. (77) July.

On a Method of Plotting the Hysteresis Loop for Iron with an Application to a Transformer.* Gisbert Kapp. (77) July.

Report of the Committee on Wiring Rules of the Institution of Electrical Engineers, 1907. (77) July.

Report of the Electrolysis Commission Appointed by the German Gas Assoc. (66) July 2.

Electric Transporters at Mersey Docks.* (11) July 5.

Electric Power Plant at the Cambrian Collieries.* (12) July 5; (22) July 5.

A New Variable Speed Electric Motor or Variable Voltage Dynamo.* L. Torda. (73) July 5.

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A. C. Electrification on the Illinois Traction System.* John R. Hewitt. (17) July 6.

The Effect of the Transmission Line Upon the Reliability and Efficiency of Electric Interurban Railway Service.* E. R. Cunningham. (17) July 6.

The Generating Station for the Taylor's Falls-Minneapolis Transmission System.* (27) July 6.

Power Plant at the Charleston Navy Yard. (27) July 6.

The Moore Vacuum Tube-Light.* (11) July 12.

Dry Battery (Railway Signalling). U. J. Fry. (40) July 12.

Inductive Disturbances to Telegraph Lines. John B. Taylor. (Paper read before the Assoc. of Ry. Telegraph Supts.) (40) July 12.

Switchboards for Testing Work.* Leonard Solomon. (73) July 12.

The New Double-Circuit Single-Phase Motor of the Felton & Guilleaume-Lahmeyer Works.* M. Osnos. (Abstract from *Elektrotechnische Zeitschrift.*) (73) July 12.

The Oscillatory Discharge in Iron Wires. A. Battelli and L. Magri. (Tr. from *Physikalische Zeitschrift.*) (73) July 12.

Compounded Alternators with Commutators.* A. Heyland. (73) July 19.

New Developments in Arc Lamps and High-Efficiency Electrodes.* G. M. Little. (Abstract of paper read before the National Elec. Light Assoc.) (73) July 19.

A Practical Limitation of Resistance Furnaces: The "Pinch" Phenomenon.* Carl Hering. (Abstract of paper read before the Amer. Electrochemical Soc.) (73) July 19.

The Elevator and Escalator Equipment of the New York Subway.* (14) July 20.

New Turbine Generating Station of the Illinois Traction System at Peoria, Ill.* (17) July 20.

Three-Wire Dynamos.* (27) July 20.

A Central Station in Bermuda, West Indies.* (27) July 20.

Cleveland (Ohio) Arcade Electrical Plant.* (27) July 20.

The Selection of Machine Insulation Material.* William S. Conant. (27) July 20.

Graphical Method of Determining Power Factor from Wattmeter Readings.* A. A. Radtke. (27) July 20.

Ground Wires and Choke-Coils for Lightning Protection. D. S. Carpenter. (27) July 20.

Induction Type Ammeters, Voltmeters and Wattmeters.* Paul MacGahan and H. W. Young. (27) July 20.

Recent Advances in Artificial Lighting (Incandescent Lamps).* (13) July 25.

Aluminium Coils. Felix Singer. (26) July 26.

The Clark Portable Wireless Telegraph Set.* A Frederick Collins. (26) July 26.

A Combined Single-Phase and Continuous-Current Series and Compensated Repulsion Motor.* E. Danielson. (Abstract from the *Elektrotechnische Zeitschrift.*) (73) July 26.

Experiments on Osram, Wolfram, Zircon and Other Lamps.* J. T. Morris and R. Milward Ellis. (73) Serial beginning July 26.

The Fleming Direct-Reading Cymometer.* A. Frederick Collins. (19) July 27.

Heating Effect of Quadrature Currents in Rotary Converters.* J. H. Hunt. (27) July 27.

Sub-station Equipment and Operation, Chicago Edison Company and Commonwealth Electric Company.* R. G. Grant. (27) July 27.

Some Notes on Alternating-Current Distribution.* A. J. Cridge. (Paper read before the Incorporated Municipal Electrical Assoc.) (46) July 27.

Electric Power Tariffs. C. S. Vesey-Brown, M. Inst. C. E. (10) Aug.

Voltage Lost in Direct-Current Wiring.* N. A. Carle. (64) Aug.

The Reconstruction of the East St. Louis & Suburban Ry. Power Station.* (14) Aug. 3.

Power Plant Inside of a Dam on the Patapsco River.* (27) Aug. 3.

A Progressive Suburban Central Station at Revere, Mass.* (27) Aug. 3.

The Financial Side of the Central Station. A. D. Williams, Jr. (27) Aug. 3.

Electric Dumb-Waiter Machines and Systems.* E. L. Dunn. (27) Aug. 3.

Hunting in Rotary Converters.* Norman G. Meade. (27) Aug. 3.

An Improved Electric Welder.* A. Frederick Collins. (46) Aug. 3.

Variations Périodiques de Vitesse dues aux Régulateurs des Moteurs.* P. Boucherot. (37) May.

Commande Electrique d'un Laminoir Réversible aux Acières Hildegardehütte (Silésie Autrichienne).* G. de Taube. (33) June 8.

La Lampe Electrique à Gaz Raréfié de M. McFarlan Moore.* (33) July 20.

Comparaison entre les Grues Hydrauliques et les Grues Electriques.* R. Gasquet. (33) July 27.

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*Illustrated.

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Internal-Combustion Engines for Marine Purposes.* James Tayler Milton. (63) Vol. 168.

Visits to European Navy Yards and Shipyards during the Summer of 1906.* Cecil H. Peabody. (7) Mar.

Building Warships by Contract; and the Duties of the Superintending Naval Constructor. A. W. Stahl. (7) Mar.

The Resistance of Ships.* A. W. Johns. (Paper read before the Inst. of Naval Archts.) (11) Apr. 26.

Design and Arrangement of Steam-Turbines.* Ernest N. Jansen. (From *Journal*, Amer. Soc. of Naval Engrs.) (11) May 3.

Pumping Machinery for the New Graving-Dock, Colombo, Ceylon.* (11) May 17.

Oil-Fuel Turbine-Driven Torpedo Boats.* (11) May 24.

A New Torsion-Meter.* B. Hopkinson and L. G. P. Thring. (11) June 14.

Machinery of the 150-Ton Hammer-Head Crane at Clydebank.* (11) June 21.

The Société des Chantiers et Ateliers de la Gironde.* (11) June 21.

Auxiliary Machinery on Merchant Steamers.* (12) June 21.

The Salving of the *Suevic*.* A. G. Hood. (15) June 28.

Some Practical Points in the Application of the Marine Steam Turbine.* C. A. Parsons and H. Wheatley Ridsdale. (Paper read before the Inst. of Naval Archts.) (11) July 12.

Structural Development in British Merchant Ships.* J. Foster-King. (Paper read before the Inst. of Naval Archts.) (11) July 19.

150-Ton Hydraulic Crane.* (12) July 19.

Gun Distribution Aboard Modern Battleships.* (From *Proceedings*, U. S. Naval Institute.) (19) Serial beginning July 20.

The Present and Future of Submarine Navigation. A. M. Laubeuf. (Abstract of paper read at the Bordeaux Inter. Cong. in Naval Architecture.) (11) July 26.

Ventilation and Refrigeration of Ammunition-Holds. Adrien Bochet. (Abstract of paper read at the Bordeaux Inter. Cong. in Naval Architecture.) (11) July 26.

The Position and Equipment of the Puget Sound Navy Yard.* H. Cole Estep. (9) Aug.

Phases d'Essais de Renfouage du Cuirassé *Montagu;* Note Annexe.* M. Dibos. (32) Mar.

Ist eine Verminderung der Zahl der [-Profile im Handelsschiffbau Durchführbar? Carl Kielhorn. (50) May 29.

Mechanical.

A Simple Rotary Distributor for Blast-Furnace Charges.* David Baker. (56) Vol. 37.

The Gas-Producer as an Auxiliary in Iron Blast-Furnace Practice. R. H. Lee. (56) Vol. 37.

The Kurzwernhart Gas-Saving Process.* Joseph Hartshorne. (56) Vol. 37.

Improvements in Rolling Iron and Steel.* James E. York. (56) Vol. 37.

The Design of Blast-Furnace Gas-Engines in Belgium.* H. Hubert. (56) Vol. 37.

The Application of Large Gas-Engines in the German Iron and Steel Industries.* K. Reinhardt. (56) Vol. 37.

Notes on Large Gas-Engines Built in Great Britain and Upon Gas-Cleaning.* Tom Westgarth. (56) Vol. 37.

Internal-Combustion Engines for Marine Purposes.* James Tayler Milton. (63) Vol. 168.

Estimation of the Unbalanced Forces in Multi-Cylinder One-Crank Engines.* Archibald Sharp. (63) Vol. 168.

The Modern Steam Turbine.* Arnold Frean Harrison. (63) Vol. 168.

Steam as a Motive Power for Public Service Vehicles.* Thomas Clarkson. (75) Nov., 1906.

Practical Pyrometry.* Robert S. Whipple. (4) Apr.

Gas Engineering. W. A. Baehr. (Paper read before the Engrs.' Club of St. Louis.) (1) May.

Peat Coke.* Max Toltz. (Paper read before the Civ. Engrs.' Soc. of St. Paul.) (1) May.

History of the Development of the Manufacture of Iron and Steel Sheets.* W. C. Cronemeyer. (58) May.

Sheet Metal Manipulation.* Frank I. Ellis. (58) May.

Some Late Improvements on Compressive Riveters and other Tools.* (58) May.

An Analysis of the Evolution of Modern Tool-Steel.* H. C. H. Carpenter. (11) Serial beginning May 3.

The Burroughs Adding and Listing-Machine.* (11) May 3.

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Valve Gear for High-Speed Engines.* A. Houlson. (47) Serial beginning May 4.

The Most Economical Mean Effective Pressure for Steam Engines.* R. Royds. (Paper read before the Inst. of Engrs. and Shipbuilders in Scotland.) (47) Serial beginning May 4.

The Best Methods of Operating Water Gas Machines. William I. Battin. (Paper read before the Illinois Gas Assoc.) (24) May 6; (83) May 15; (66) May 28.

Economy in Power. A. Stucki. (15) May 10.

Modern Power Plant at the "Argyll Motors" Works, Alexandria, Glasgow.* (26) May 10.

The Production of Coke and Its Application in Domestic Fires.* Paul Schlicht. (29) May 10.

An Electrically-Driven Cement Works.* (73) May 17; (26) May 17.

Effect of Size on the Thermal Efficiency of Explosion Motors. H. L. Callendar. (Paper read before the Inst. of Automobile Engrs.) (47) Serial beginning May 18.

A Floating Derrick for Handling Heavy Rip-rap Stone.* (13) May 23.

The Art of Galvanizing. Alfred Sang. (Paper read before the Amer. Foundrymen's Assoc.) (20) Serial beginning May 23; (62) June 15; (19) Serial beginning July 13.

Dust-Fuel Stokers and Auxiliary Plant. W. R. Harrison. (Paper read before the Leeds Univ. Eng. Soc.) (22) May 24.

Judging Coke from its Appearance.* A. Thau. (Tr. from *Glückauf.*) (22) May 24.

Steel Coal Tipples.* C. W. Brooks. (86) May 24.

Aerial Locomotion.* Alexander Graham Bell. (From the *National Geographic Magazine.*) (19) May 25.

Gas Manufacturing from Peat.* Philip I. Cohen. (66) May 28.

A Review of the United States Geological Survey Fuel Tests Under Steam Boilers.* L. P. Breckenridge. (4) June.

The Properties and Use of Mineral Oils.* P. F. Walker. (9) June.

Efficiency in the Burning of Fuel under the Steam Boiler.* William D. Ennis. (9) Serial beginning June.

The Design of Modern Producers and Gas Engines.* R. E. Mathot. (9) June.

How to Set a Riding Cut-Off Valve.* Hubert E. Collins. (64) June.

First Rateau Regenerator Installed in America.* F. G. Gasche. (64) June.

Formulas for the Flow of Steam in Pipes.* G. F. Gebhardt. (64) June.

Note on Suction Producer Plant.* A. E. Porte. (77) June.

The Design and Construction of Foundry Buildings. Geo. K. Hooper. (Paper read before the Amer. Foundrymen's Assoc.) (14) June 1.

The Woodall-Duckham Vertical Retort-Settings.* (66) June 4.

Purification. G. H. Niven. (Paper read before the Inst. of Gas Engrs.) (66) June 4.

Estimation of Tar Fog and Its Separation from Gases.* R. H. Clayton and F. W. Skirrow. (66) June 4.

Gas-Engine Efficiencies.* Leonard Bairstow. (11) June 7.

Working Experiences with Large Gas Engines.* Cecil A. St. George Moore. (Abstract of paper read before the Soc. of Engrs.) (22) June 7; (47) Serial beginning June 15.

Turbo-Alternators for Sydney, N. S. W.* (22) June 7.

Governors for High-Speed Engines.* A. Houlson. (47) Serial beginning June 8.

A By-Product Coking Plant at Clay Cross.* W. B. M. Jackson. (Paper read before the Inst. of Min. Engrs.) (22) June 14.

Notes on By-Product Coke-Ovens with Special Reference to the Koppers Oven.* A. Victor Kochs. (Paper read before the Inst. of Min. Engrs.) (22) June 14.

How to Build a 5-Horse-Power Stationary Engine.* E. F. Lake. (19) Serial beginning June 15.

Steam Traps. Gordon Stewart. (Abstract of paper read before the Civ. and Mech. Engrs.' Soc.) (47) June 15.

Bench Fuel Economies. F. M. Richards. (Abstract of paper read before the Wisconsin Gas Assoc.) (83) June 15; (66) June 11.

The Mannheim Gas-Works. J. Pichler. (Paper read before the German Assoc. of Gas and Water Engrs.) (66) June 18.

The Vertical Retort-House at the Oberspree (Berlin) Gas-Works.* E. Körting. (Paper read before the German Gas Assoc.) (66) June 18; (24) July 8.

Stamp End Works, Lincoln.* (11) June 21.

The Separation of the Iron Losses in Asynchronous Machines.* Thos. F. Wall. (73) June 21.

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Recent Steam Turbine Developments. W. L. R. Emmet. (Abstract of paper read before the National Elec. Light Assoc.) (14) June 22.
Mechanical Production of Low Temperatures.* Sydney F. Walker. (16) June 22.
Recent Progress in Producer Gas Power Installations.* Godfrey M. S. Tait. (19) June 22.
High Pressure Distribution Development in the United States.* R. M. Searle. (Paper read before the Inst. of Gas Engrs.) (66) June 25; (83) July 1; (24) July 15.
Brown-Boveri Steam Turbines in the Rhenanian-Westphalian Industrial District.* Alfred Gradenwitz. (26) June 28.
The Disposal of Smelter Smoke. Herbert Lang. (16) June 29.
Heat Production and the Constituents of Coal.* S. W. Parr. (16) June 29.
Modern Abrasive Materials and Their Use in Shop Practice.* J. Royden Peirce. (47) June 29.
Superheated Steam.* Thomas Sugden, M. Inst. Mech. Engrs. (Paper read before the South Wales Inst. of Engrs.) (47) Serial beginning June 29.
The Interchange of Heat in Steam-Engine Cylinders. W. F. Cleveland. (9) July.
Gas and Electric Power in Continental Iron and Steel Works.* J. B. van Brussel. (9) July.
General Principles in the Construction of Modern Gas Producers.* R. E. Mathot. (9) July.
The Steam Turbine.* Charles Proteus Steinmetz. (10) July.
Some Recent Developments in Machine Tools.* Joseph Horner. (10) Serial beginning July.
Marshall's Valve Gear.* (21) July.
Electric Crane Lifting Magnets.* (41) July.
Elimination of Friction in Ball Bearings.* J. F. Springer. (64) July.
The Remodeled Rollins Engine.* (64) July.
How Should the Feed Water be Heated?* A. J. Albright. (64) July.
A Steam Plant for Developing One Hundred Horse-power.* James F. Hobart. (64) July.
A Model Hotel Plant.* M. B. Godfrey. (64) July.
Steam-power Plant of One Hundred Horsepower Capacity.* C. R. McGahey. (64) July.
The Gas Power Plant of the Norton Company.* (64) July.
Most Efficient Ratio of Steam Cylinders in Direct-Acting Compound Pumps.* F. F. Nickel. (64) July.
The Steam Engine Versus the Gas Engine. (64) July.
Capacities of Cast Iron Sectional Boilers. Kenneth Gray. (Paper read before the British Inst. of Heating and Ventilating Engrs.) (70) July.
A New Departure in Cooling and Humidifying Textile Mills.* W. H. Carrier. (Abstract of paper read before the Amer. Assoc. of Cotton Mfrs.) (70) July.
Standard Methods in Service, Meter, Appliance and House Fitting.* G. I. Vincent. (Paper read before the Iowa District Gas Assoc.) (24) July 1.
The Adjustment of the Gas Supply to Inverted Burners.* (66) July 2.
Report of the Electrolysis Commission Appointed by the German Gas Assoc. (66) July 2.
Report of the Gas-Meter Commission Appointed by the German Gas Assoc. (66) July 2.
The Carbonisation of Coal, with Special Reference to the By-Product Coking Process.* Ernest Bury. (Abstract of paper read before the Inst. of Gas Engrs.) (22) July 5.
A New Impact Test.* L. W. Page. (Paper read before the Amer. Soc. for Testing Materials.) (14) July 6.
Waste Heat Boilers for Copper Smelting Furnaces.* (14) July 6.
Steam Turbines for Sydney, New South Wales.* (17) July 6.
Santos Dumont's Combined Aeroplane and Airship.* (46) July 6.
Welding and Shaping Link Chains.* (47) July 6.
New Valve Gear for Internal-Combustion Engines.* (47) July 6.
The McMillan Smokeless Furnace Exhibited at Milwaukee.* (62) July 8.
Report of the Cleveland Municipal Committee on the Smoke Nuisance. (62) July 8.
Carbonization of Durham Coking Coal. Andrew Short. (Reprinted from the *Journal* of the Soc. of Chemical Industry.) (66) July 9.
The Lidgerwood Electric Friction-Drum Winches for Car Ferries.* (13) July 11.
Coal and Coke Handling at the Astoria Light, Heat & Power Co.'s Plant, Astoria, L. I.* Alfred Kauffmann. (13) July 11.

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Foundry Design. F. A. Coleman. (Paper read before the Amer. Foundrymen's Assoc.) (20) July 11.
Autogenous Welding.* (20) July 11; (41) July; (18) July 6; (13) June 27.
Beasley's Recording Gas-Calorimeter.* (11) July 12.
Some Practical Points in the Application of the Marine Steam Turbine.* C. A. Parsons and H. Wheatley Ridsdale. (Paper read before the Inst. of Naval Archts.) (11) July 12.
Steam Vehicle Trains for Highway Operation.* (18) July 13.
Amorphous Graphite as a Lubricant. H. C. Woodruff. (18) July 13.
An Aeronautical Observatory.* Alfred Gradenwitz. (19) July 13.
A Traction Wheel with Sinusoidal Tread.* (46) July 13.
Captive Balloons in the German Army and Navy.* Alfred Gradenwitz. (46) July 13.
Roots' Two-Stroke Cycle Internal Combustion Engine.* (47) July 13.
Worthington's Compensating Direct-Acting Engine.* (47) July 13.
Changing a Plant from Artificial to Natural Gas. Geo. W. Barnes. (Paper read before the Natural Gas Assoc. of America.) (83) July 15.
Incandescent Gas Lighting with Special Reference to Inverted Burners. Harold E. Copp. (Abstract of paper read before the British Inst. of Gas Engrs.) (83) July 15.
The Sarco Automatic Combustion Recorder.* (20) July 18.
Tests for Isolating Valves for Steam-Pipes. (11) July 19.
Kermodes Liquid-Fuel System Applied to Babcock and Wilcox Boilers.* (11) July 19.
Compound Pneumatic Hammer.* (12) July 19.
Huddersfield Corporation Electricity Works: Compound Piston Drop Valve Engine.* (12) July 19.
New Machine for Drawing and Loading Coke.* W. M. Nixon. (16) July 20.
Autogenous Welding of Metals. Ernest Schneider. (Abstract from paper read before the Workmen's Union, Chemnitz, Germany.) (19) July 20.
Standard Test Burner for London Gas. Charles Carpenter and James W. Helps. (Paper read before the Inter. Committee on Photometry.) (66) July 23.
Special Derricks and Buckets for the Construction of a Reinforced Concrete Warehouse at Chicago.* (13) July 25.
The Riverside Metal Company's New Rolling Mill Plant.* (20) July 25.
Hydraulic Riveting.* E. W. De Rusett. (Paper read at the Bordeaux Inter. Cong. in Naval Architecture.) (11) July 26.
Engines of the Steam-Yacht *Medusa*.* (11) July 26.
On the Design of Machinery for Very High Pressures.* J. E. Petavel. (11) July 26.
Tests of Staybolts and Staybolt Iron.* E. L. Hancock. (Paper read before the Amer. Soc. for Testing Materials.) (40) July 26.
Power Plant of the West Street Building, New York City.* (14) July 27.
The Steam Power Station of the Twin City Rapid Transit Company, Minneapolis.* (17) July 27.
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Valve Ellipse Indicator.* (25) Aug.
Some Notes on the Tests at the St. Louis Exposition.* H. H. Vaughan. (From paper read before the Canadian Ry. Club.) (25) Aug.
Fuel Losses in Steam Power Plants. Geo. H. Barnes. (10) Aug.
Safety Appliances in the Engine Room.* William Wallace Christie. (10) Aug.
Modern Jib and Locomotive Cranes.* (41) Aug.
Adjusting the Sturtevant Compound Engine.* Carl S. Dow. (64) Aug.
Producer Gas for Firing Steam Boilers.* A. M. Gow. (64) Aug.
The Operation and Care of Injectors.* W. H. Wakeman. (64) Aug.
A Useful Diagram of Steam Properties.* H. F. Schmidt and W. C. Way. (64) Aug.
Apparatus for Analyzing Flue Gases.* (64) Aug.
Suction Gas Producer Plant at Rocky Ford, Colo.* (64) Aug.
Different Styles of Connecting-Rods Compared.* C. R. McGahey. (64) Aug.
A Wire-Wound Wood-Rim Fly-Wheel.* E. E. Clock. (64) Aug.
Approved Proportions of Flange Couplings, Clutches and Wrenches (Tables).* John D. Adams. (64) Aug.
Gravel Screening and Washing Plants.* (13) Aug. 1.
Methods Followed in Making Becker-Brainard Milling Machine Castings.* Henry M. Lane. (20) Aug. 1.
High Pressure Transmission (of Gas). R. H. Lawlor. (Paper read before Iowa District Gas Assoc.) (83) Aug. 1.
Standard Methods in Pipe Fitting (Gas).* G. I. Vincent. (Paper read before the Iowa District Gas Assoc.) (83) Aug. 1.
Motor Starting Devices for Gasoline Automobiles.* Harold H. Brown. (19) Aug. 3.

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The Present Status of Candle Power Standards for Gas. C. H. Stone. (Paper read before the Illuminating Eng. Soc.) (24) Aug. 5.
Advantages of Mechanical Stoking as Smoke Abaters.* Paul M. Chamberlain. (Lecture before the International Assoc. for the Prevention of Smoke.) (62) Aug. 5.
Etat Actuel de l'Industrie Frigorifique.* Ch. Lambert. (32) Apr.
Carburateurs Divers.* (37) Apr.
Train Automobile de la Société Freibahn pour le Transport des Marchandises.* A. Bidault des Chaumes. (33) Apr. 27.
Représentation du Fonctionnement Théorique des Gazogènes au Coke.* Rodolphe Soreau. (32) May.
Des Huiles à Graisser.* Ch. Baron. (32) May.
Note sur l'Allumage Electrique des Moteurs à Gaz et à Pétrole.* H. Lhonoré. (37) May.
Gazogène à Combustible Pulvérisé, système Marconnet.* (33) May 11.
La Voiture Pétroléo-Electrique. Système Kriéger.* F. Drouin. (33) June 1.
Appareil pour Faire Circuler l'Eau Méthodiquement dans les Chaudières Ignitubulaires ou à Foyers Intérieurs.* (33) June 22.
Production Economique de la Force Motrice au Moyen de Gaz Métallurgiques.* Ch. Dantin. (33) June 29.
Un Dirigeable Allemand: *Le Zeppelin.** G. Espitallier. (33) July 6.
Machine à Fabriquer les Bouteilles en Verre, Système Leistner.* (33) July 13.
Comparaison entre les Grues Hydrauliques et les Grues Electriques.* R. Gasquet. (33) July 27.
Die Beanspruchung von Drahtseilen. J. Isaachsen. (48) Apr. 27.
Selbsttätiger Gegenstrom- und Wasserumlauf-Erzeuger von Kunert für Flamm- und Heizrohrkessel.* Dr. Förster. (48) Apr. 27.
Ein Modernes Platinen-Triowalzwerk.* (50) May 8.
Temperaturspannungen in Hohlzylindern.* Rudolf Lorenz. (48) May 11.
Ergebnisse der Untersuchung eines bei der Druckprobe Aufgerissenen Kesselbleches.* C. Bach. (48) May 11.
Neuere Ziele und Erfolge des Deutschen Wärmekraftmaschinenbaues.* H. Dubbel. (48) Serial beginning May 18.
Ueber Gasgeneratoren.* (Discussion.) (50) June 5.
Rauchverbrennung.* (82) June 29.
Zur Frage der Rissbildung in Kesselblechen.* Eichhoff. (50) July 3.
Hebe- und Transportmittel in Stahl- und Walzwerksbetrieben.* G. Stauber. (Paper read before the Verein Deutscher Eisenhüttenleute.) (50) July 10.
Taylors Untersuchungen über Rationelle Dreharbeit. A. Wallichs and O. Petersen. (50) July 17.
Wärmespannungen und Rissbildungen.* Carl Sulzer. (48) July 27.
Hochbau-Mastenkrane.* Georg W. Koehler. (48) July 27.

Metallurgical.

Fine Grinding of Ore by Tube-Mills, and Cyaniding at El Oro, Mexico.* G. Caetani and E. Burt. (56) Vol. 37.
The Amalgamation of Gold-Ores.* Thomas T. Read. (56) Vol. 37.
Notes on the Gayley Dry-Air Blast-Process.* C. A. Meissner. (56) Vol. 37.
Piping in Steel Ingots.* N. Lilienberg. (56) Vol. 37.
The Washoe Plant of the Anaconda Copper-Mining Co. in 1905.* L. S. Austin. (56) Vol. 37.
Heat-Treatment of Steels Containing Fifty Hundredths and Eighty Hundredths Per Cent. of Carbon.* C. E. Corson. (56) Vol. 37.
The Crystallography of Iron.* F. Osmond and G. Cartand. (56) Vol. 37.
The Cyanidation of Raw Pyritic Concentrates. Frank C. Smith. (56) Vol. 37.
The Lime-Roasting of Galena. W. R. Ingalls. (56) Vol. 37.
The Secondary Enrichment of Copper-Iron Sulphides. Thomas T. Read. (56) Vol. 37.
The Mining, Preparation and Smelting of Virginia Zinc-Ores.* Thomas Leonard Watson. (56) Vol. 37.
Stamp-Mill Reduction-Plant of the New Kleinfontein Company, Limited, Witwatersrand, Transvaal. Edward John Way. (63) Vol. 168.
Vanadium Steels in Railroad Practice. J. Kent Smith. (Extracts from paper read before the Central Ry. Club.) (18) May 4.
Ore Concentration by Oil.* (12) May 10.
Vacuum-flotation Process for Concentration.* Alexander Stanley Elmore. (16) May 11.
Magnetic Separation of Iron Ore in Sweden.* G. Walfrid Petersson. (Tr. by N. V. Hansell.) (16) May 11.
Tin Ore Dressing Plant, East Pool, Cornwall.* Edward Walker. (16) May 18.
Compression of Steel Ingots by Wire Drawing.* E. L. Zalinski. (From the *Journal of the U. S. Artillery.*) (15) May 24.

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Chrome Plant of the U. S. Metals Refining Company.* Lawrence Addicks. (16) May 25.
Change of Structure in Iron and Steel.* Wm. Campbell. (3) June.
Milling at Gladstone, Colo.* Geo. P. Scholl. (45) June.
Stack Extension of Copper Queen Smelter, Douglas, Ariz.* (45) June.
The Use of Graphic Formulas in Metallurgical Calculations.* D. H. Browne. (Paper read before the Canadian Inst.) (45) June.
Zinc Oxide and Zinc-Lead Pigment Manufacture.* William F. Gordon. (16) June 1.
Behaviour of Carbon and Phosphorus in Steel.* Henry M. Howe. (16) June 8.
Method for Analysis of Gold-Silver Bullion. J. E. Clennell. (16) June 8.
Practice at the Osceola Mill, Lake Superior.* Lee Fraser. (16) June 22.
Extract of Report on the Methods Used to Avoid Piping in Steel Ingots, As Applied in the Hungarian Government Steel Foundries at Diosgyör.* Albert Obholzer. (3) July; (62) July 22.
A Modern Copper Converter.* G. B Shipley. (45) July.
The Systematic Treatment of Metalliferous Waste. L. Parry. (68) Serial beginning July 6.
The Electrolytic Process of Copper Recovery. Walter Stoeger. (Tr. from *Metallurgie.*) (68) Serial beginning July 6.
Rail Steel as Manufactured by the Continuous Open-Hearth Process at Cargo Fleet.* Benjamin Talbot. (Paper read before the Amer. Soc. for Testing Materials.) (22) July 12.
Milling "Sheet Ground" Ore in Joplin (Mo.) District.* Doss Brittain. (16) July 13.
Vanadium Steel. J. Kent Smith. (62) July 15.
An Example of Blast Furnace Reconstruction (Richard Heckscher & Sons Company's Plant).* (20) July 25.
The Modern American Blast Furnace.* Bradley Stoughton. (16) Serial beginning July 27.
Copper-Smelting Practice in the Boundary District, British Columbia.* Frederic Keffer. (9) Aug.
The Largest Copper Smelting Plant in the World.* (13) Aug. 1.
L'Aluminothermie et ses Applications.* J. Feugères. (34) May.
L'Utilisation Industrielle de la Métallographie Microscopique.* Léon Guillet. (33) Serial beginning June 15.
Cubilot à Récupération, Système A. Baillot.* Ch. Dantin. (33) June 15.
L'Electro-Sidérurgie.* Jean Escard. (34) Serial beginning July.
Die Hochofen-, Stahl- und Walzwerksanlage der "Società Anonima degli Alti Forni e Fonderia di Piombino."* Fritz Lürmann, Jr. (50) May 1.
Chrom-Nickelstähle. Kedesdy. (Abstract from article by Guillet in *Revue de Métallurgie.*) (50) May 8.
Ueber Gasgeneratoren. Johannes Körting. (Paper read before the Verein Deutscher Eisenhüttenleute.) (50) May 15.
Chemische und Metallographische Untersuchungen des Hartgusses.* H. Wedding and Fritz Cremer. (50) Serial beginning June 12.
Erzrösten.* Carl Wetzel. (82) Serial beginning June 29.
Das Turbinengebläse von C. A. Parsons als Hochofengebläsemaschine.* Julius Fürstenau. (48) July 20.
Ueber den Augenblicklichen Stand Unserer Kenntnisse der Erstarrungs- und Erkaltungsvorgänge bei Eisenkohlenstofflegierungen. P. Goerens. (50) July 24.

Military.

105-Millimetre and 120-Millimetre Quick-Firing Field Howitzers.* (11) May 10.
Birmingham Small Arms.* (12) May 10.
The Coventry Ordnance Works, Limited.* (12) Serial beginning May 31.
The New Vickers-Maxim Automatic Rifle-Calibre Gun.* (46) Aug 3.

Mining.

Methods of Mining, Hauling and Screening at the Mines of the Aldrich Mining Company, at Brilliant, Alabama.* T. H. Aldrich. (56) Vol. 37.
The Relative Merits of Large and Small Drilling Machines in Development Work.* Frederick T. Williams. (56) Vol. 37.
The Beard-Mackie Sight-Indicator for the Measurement of Marsh-Gas in Collieries.* M. H. Harrington. (56) Vol. 37.
Bibliography of Coal-Washing. Samuel S. Wyer. (56) Vol. 37.
Screens for Sizing. Ernest A. Hersam. (56) Vol. 37.
The Mining, Preparation and Smelting of Virginia Zinc-Ores.* Thomas Leonard Watson. (56) Vol. 37.

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A Novel Method of Mining Kaolin. Albert R. Ledoux. (56) Vol. 37.
Gold-Dredging in the Urals, with Notes on Dredging in Siberia.* William H. Shockley. (56) Vol. 37.
The Hanley Cage Guardian.* (59) Vol. 29, Pt. 4.
Some Notes on the Mechanical Equipment of Collieries.* E. M. Hann. (75) Oct., 1906.
Notes on the Electrical Installation at Swalwell Garesfield Colliery.* Jackson Swindle. (Paper read before the National Assoc. of Colliery Mgrs.) (22) Apr. 26.
Electric Power in Durham Collieries.* (26) Serial beginning Apr. 26.
Colliery Hoisting, Haulage and Power Systems.* Franz Erich Junge. (16) May 11.
Four Tests of a Capell Mine Ventilating Fan.* John B. Thomson. (16) May 25.
The Electrical Equipment of the Yak Tunnel.* Robert E. Renz. (16) May 25.
Methods Used in Surveys of Coal Mines.* L. D. Tracy, Assoc. M. Am. Soc. C. E. (13) May 30.
Methods of Mining in the Boundary District, British Columbia.* Frederic Keffer. (9) June.
Stresses in Hoisting Ropes. James F. Howe. (45) June.
Hydraulic Mining.* William W. Harts. (45) June.
Process of Coal Washing.* Samuel Diescher. (58) June.
Description of Washing Plants in Operation.* W. G. Wilkins. (58) June.
Mining Coal. Lee C. Moore. (58) June.
The Electric Power Installation at Grangesberg Iron Mines, Sweden.* G. Ralph. (Abstract.) (77) June.
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An Alternating-Current Coal-Mining Installation.* T. W. Sprague and C. K. Stearns. (16) June 8.
Operation and Equipment of the St. Clair Colliery.* Floyd W. Parsons. (16) June 15.
The Progress of Mining in Great Britain in Recent Years. M. Deacon. (Abstract of paper read before the Inst. of Min. Engrs.) (68) Serial beginning June 22.
The Tibetan Goldfields.* Malcolm Maclaren. (68) June 22.
Recent Improvements at the Clausthal Mines.* Bergrat Schennen. (68) June 22.
Gold-Dredging Practice at Ruby, Montana.* J. P. Hutchins. (16) Serial beginning June 29.
The Schuyler Mine.* J. H. Granbery, Assoc. M. Am. Soc. C. E. (3) Serial beginning July.
Explosion of Air Locomotive.* (45) July.
Concrete Roof Supports.* (45) July.
Lead-Silver Deposits of Mowry, Ariz., the Caving System of Mining 80 Per Cent. of the Ore without Timbering.* R. B. Brinsmade. (45) July.
The Panel Retreating System.* S. J. Jennings. (45) July.
Wood *versus* Iron for Pipe Lines in Coal Mines. John H. Haertter. (16) July 6.
Modern Methods of Washing Bituminous Coal.* Floyd W. Parsons. (16) July 6.
Alternating Current in Coal-Mining Operations.* George R. Wood. (16) July 6.
Working Flat and Pitching Anthracite Seams.* M. S. Hachita. (16) July 6.
Electric Installation at the Cambrian Collieries Limited.* (57) July 12.
Practical Experiments in Coal-Mine Ventilation. W. D. Owens. (16) July 13.
The Syracuse Shaft on the Mesabi: How a Shaft Was Sunk Through Quicksand by Pneumatic Process.* (16) July 13; (14) July 13.
The Turned-back Shaft at the Salisbury Mines.* Reginald Meeks. (16) July 13.
A Complete Description of Washing Plants in Operation.* W. G. Wilkins. (62) July 15.
Ventilation of Shafts During Sinking Operations.* (22) July 19.
Fan Ventilators for Mines. Robert Grimshaw. (16) July 20.
The Caving System on the Menominee Range.* Reginald Meeks. (16) July 20.
Some Practical Points on Mine Surveying. Laurence C. Hodson. (Reprinted from *Iowa Engineer.*) (16) July 20.
Stoping with the Air-Hammer Drill.* G. E. Wolcott. (16) July 20.
The Treatment of Anthracite Coal.* (22) July 26.
Ferro-Concrete Lining for Mine Galleries.* (From *Zeitschrift für Berg-, Hütten- und Salinenwesen.*) (57) July 26.

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Mining—(Continued).

Rack-rail Haulage in Coal Mines.* George E. Lynch. (16) Aug. 3.
Subsidence in Underground Mines.* Alexander Richardson. (Abstracted from *Journal*, Chemical, Metallurgical and Mining Soc. of South Africa.) (16) Aug. 3.
Revêtements de Galeries en Béton Armé aux Mines de Béthune.* Lombois. (Abstract from *Bulletin de la Société de l'Industrie Minérale.*) (33) June 8.
L'Enrichissement des Minérais par l'Huile procédé Elmore.* (33) June 29.

Miscellaneous.

Principle and Operation of the Féry Radiation Pyrometer.* C. H. Wilson and Frederick Maeulen. (6) Apr.
Building a Town Site by Suction Dredge.* Day Allen Willey. (46) May 25.
Pyrometry in Modern Workshop Practice.* Chas. R. Darling. (Abstract of Lecture at the City and Guilds Technical College, Finsbury, E. C.) (12) June 14.
The Enforcement of Specifications. Charles B. Dudley. (Paper read before the Amer. Soc. for Testing Materials.) (14) June 29; (13) July 4.
"Flexibles" with Notes on the Testing of Rubber.* Alfred Schwartz. (77) July.
Engineering Education. (Abstracts of papers read before the Soc. for the Promotion of Eng. Education.) (18) July 6.
Some Facts About Dynamite: The Chemistry of a Powerful Explosive. (19) July 20.
Comparisons of Light-Standards: Report made by the National Physical Laboratory to the Inst. of Gas Engrs.* (66) July 23.
Determining Volumes of Coal in Bins and Piles.* Charles Enzian. (16) July 27.
De la Dispersion Artificielle du Brouillard.* M. Dibos. (32) Mar.
Le Papier et sa Fabrication à Travers les Ages.* A. Blanchet. (32) May.

Municipal.

First Prize Paper on Best Methods of Draining Roadbeds.* Albert Cramblit. (87) May.
The Maintenance of Asphalt Pavements. S. Whinery, M. Am. Soc. C. E. (13) May 9.
Tar Macadam Pavement in Duluth, Minn. E. K. Coe. (13) May 30.
The Development of Street Pavements.* George W. Tillson. (3) June.
Brick Pavements.* (60) June.
Second Prize Paper on Best Methods of Draining Roadbed.* T. J. Scanlin. (87) June.
Recent Progress in the Asphalt Paving Industry. Clifford Richardson. (Abstract of paper read before the Soc. of Chemical Industry.) (14) June 1.
The Use of Tar on Roadways. H. P. Maybury. (Paper read before the Inst. of Gas Engrs.) (66) June 25.
A New Automobile Race Track.* (46) July 6.
Suggested Specifications for Street Lighting: Report to the National Elec. Light Assoc. (14) July 20.
The Municipal Works of Gary, Ind.* (14) July 20.
Notes on Tar Macadam. C. F. Wike. (Abstract of paper read before the Assoc. of Municipal and County Engrs.) (66) July 23.
Cement Filler for Brick Pavements.* (60) Aug.
Rapport d'Ensemble sur les Moyens Employés jusqu'ici pour Combattre la Poussière des Routes, Presenté à la Commission d'Etudes Instituée par M. le Ministre des Travaux Publics. Le Gavrian. (43) 1907, Pt. II.

Railroad.

Comparison of American and Foreign Rail-Specifications, with a Proposed Standard Specification to Cover American Rails Rolled for Export. Albert Ladd Colby. (56) Vol. 37.
The Simplon Tunnel.* Francis Fox. (63) Vol. 168.
The Design of Wayside Stations for Single Lines of Railway.* Frederick George Royal-Dawson. (63) Vol. 168.
Railway-Motor-Car Traffic.* T. Hurry Riches and Sidney B. Haslam. (75) Dec., 1906.
Lighting of Railway Premises: Indoor and Outdoor.* Henry Fowler. (75) Dec., 1906.
Single Phase Railways.* F. E. Wynne. (2) Apr.
Vibrations in Passenger Trains From High Speed Electric Lighting Engines.* F. W. Huels. (4) Apr.
Notes on Three-Phase Traction. Gerard B. Werner. (6) Apr.
Electric Train Lighting. O. W. Ott. (61) Apr.
Gasoline Motor Cars for Railway Service.* W. R. McKeen, Jr. (65) Apr.

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Regenerative Control of Electric Tramcars and Locomotives.* Alfred Raworth. (77) Apr.
The Modern Locomotive.* Paul T. Warner. (3) May.
Underground Stations at Finsbury Park; Great Northern Railway.* Chas. S. Lake. (21) May.
Low Pressure Pneumatic Signalling at Ermont; Northern Railway of France.* (21) May.
200-Mile Run with a De-Glehn *Atlantic* Engine.* (21) May.
Heavy 0-8-4 Three-Cylinder Shunting Tank-Engines; Great Central Railway.* (21) May.
Automatic Signals in Woodhead Tunnel.* (21) May.
Maintenance and Repair of Steel Freight Cars, Baltimore & Ohio Railroad.* (25) May.
Locomotive Piston Valves.* Hal. R. Stafford. (25) May.
Four-Cylinder Simple Ten-Wheel Locomotive; London and Southwestern Railway.* Chas. S. Lake. (25) May.
Tonnage Rating. (25) May.
Report of Committee of Western Ry. Club, on Delay in Movement of Empty Cars at Terminals. (61) May.
New York, New Haven & Hartford Improvement at Providence.* (40) May 3.
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Locomotive Testing Plant of the Pennsylvania Railroad at Altoona.* (18) May 4.
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The 16th Street Track Elevation of the Burlington at Chicago.* (15) May 10.
Freight Terminal of the Central of New Jersey in the Bronx.* (40) May 10.
Comparison of Third Rail and Overhead Trolley Construction as Applied to the Electrification of Steam Roads. (17) May 11.
Improvements on the Chicago Division of the Cleveland, Cincinnati, Chicago & St. Louis Ry.* (13) May 16.
Line Changes and Extensions of the Oregon Railroad & Navigation Company's System in Oregon and Washington.* W. P. Hardesty. (13) May 16.
Rack Locomotive for the Transandine Railway.* (11) May 17.
Defective Rails.* (15) May 17.
The Mallet Compound Locomotives on the Great Northern. (15) May 17; (25) June; (47) May 25; (18) June 8.
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The Karawanken Tunnel.* (12) May 24.
Air Brake Control on Heavy Grades of Trains Composed Exclusively of Fully Loaded 100 000 Lbs. Capacity Cars. T. L. Burton. (Abstract of paper read before the Air-Brake Assoc.) (15) May 24.
Prussian State Railway Signals.* W. H. Pockels. (15) May 24.
The Ft. Dodge, Des Moines & Southern Railway.* (40) May 24; (72) May 25.
Sections of 90-pound Rails Broken in Service.* (40) May 24.
The Verity Dalziel System of Train Lighting.* (73) May 24.
Locomotive Coaling Stations.* A. J. Webster. (86) May 24.
An Indian Territory Interurban System.* (17) May 25.
Rail Specifications for Chicago. (17) May 25.
Physical Conditions which Affect Rail Making.* A. W. Heinle. (62) May 25.
Electric Railway Assoc.; Report of the Standardization Committee.* (72) May 25; (Abstract.) (18) July 13.
Proposed Union Station at Ottawa.* (15) May 31.
The Single-Phase Railroad of the Brembana Valley (Italy).* E. A. Kerbaker. (26) May 31; (17) July 6.
A Vital Electric Traction Problem.* (Abstract from *Electrical Age.*) (73) May 31.
Results obtained by the Use of Car Meters.* (73) May 31.
Some Remarkable Locomotives of 1906. J. F. Gairns. (10) June.
4-6-0 Engines; Buenos Ayres and Pacific Railway.* (21) June.
The New Roof at Charing Cross Terminus, South Eastern Railway.* Chas. S. Lake. (21) June.
4-4-2 Engines (with Superheaters); Swedish State Railways.* (21) June.
Automatic Signals for Light Railways and Tramways.* (21) June.
Steel Passenger Equipment. Charles E. Barra and Marvin Singer. (25) Serial beginning June.
75-Ton Steel Flat Car, Lake Shore & Michigan Southern Railway.* (25) June.
A Tabular Comparison of Notable Examples of Recent Locomotives. (25) June.

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Simple Ten Wheel Locomotive, Chicago & Northwestern Railway.* (25) June; (15) July 5.

All Steel Passenger Service Cars, Pennsylvania Railroad.* (25) Serial beginning June; (18) Serial beginning June 8; (17) June 8; (40) June 7; (13) June 20; (15) June 14.

Simple Locomotive Fitted with Improved Smoke Tube Superheater, Swiss Government Railroad.* Wilhelm Schmidt. (25) June.

Concrete Railway Ties. (67) June.

Specifications for Tie Treatment.* (87) June.

Electric Car Braking.* H. T. Plumb. (Abstract of paper read before the Indiana Eng. Soc.) (17) June 1.

Air Brakes on the New York Central Electrical Equipment.* S. W. Dudley. (Extracts from paper read before the Air Brake Assoc.) (18) June 1.

Recent Developments in Air Brake Control Apparatus.* F. H. Parke and S. W. Dudley. (15) June 7.

A Solution of the Oil-Burning Locomotive Problem.* Harrington Emerson. (15) June 7.

De Glehn Compound for the Paris-Orleans Railway.* (15) June 7.

Changing the Gage on the Louisville and Nashville.* Reuben Wells. (15) June 7.

Pacific Locomotive for the Atlanta & West Point.* (15) June 7; (40) July 19.

Compression in Locomotive Cylinders and Means for its Relief.* H. G. Manning. (15) June 7.

Moment of Inertia and Curvature.* G. R. Henderson. (15) June 7.

The Electricity Generating Station of the Great Eastern Railway Co.* (73) June 7.

The Belmont Tunnel, New York.* (14) June 8.

Driving Concrete Piles below the Battery Tunnel, New York. (14) June 8.

New Power Plant of the Central Pennsylvania Traction Co. at Harrisburg, Pa.* (14) June 8.

West Shore Electrification between Utica and Syracuse.* (17) June 8; (72) June 22; (40) June 21; (13) June 27.

The Electrical Maintenance Plants of the New York Central & Hudson River Railroad.* (17) June 8.

Machine Tool Equipment of the E. P. & S. W. Ry., El Paso, Tex., Shops.* (18) June 8.

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Steam and Electric Locomotive Terminals of the New York Central at Croton and North White Plains.* (15) June 14.

A Comparison of Cooper's E50 Loading with Recent Heavy Locomotives.* (13) June 15.

Structural Steel in Freight Car Construction.* G. A. Akerlind. (Paper read before the Scandinavian Tech. Soc.) (18) June 15.

New Tank Locomotive for the Midland Railway.* (47) June 15.

The Philadelphia & Western Railway.* (72) June 15; (17) June 15.

A Test of Insulators for an Exceptional Service.* Sidney Sprout. (72) June 15.

New Steel Cars of the Hudson Companies.* Hugh Hazleton. (72) June 15; (40) June 14; (15) June 14; (17) June 8.

Locomotive Fireboxes with Expansion Sheets.* (Abstract of report of Supt. Motive Power, Hocking Valley Ry.) (13) June 20.

Pacific Type Locomotive for Heavy Express Service on the Pennsylvania R. R.* (13) June 20.

Revision of Standards and Recommended Practice.* (Report of Committee to Master Car Builders Assoc.) (15) June 21.

The Tehuantepec National Railway.* (14) June 22.

New Power Plant of the Pittsfield Electric Street Railway Company.* (17) June 22.

Consolidation (2-8-0) Type Compound Locomotive, St. Gothard Railway.* (47) June 22; (21) July.

A New 100-Lb. Rail Section.* (13) June 27.

Open Hearth Steel Rails.* Benjamin Talbot. (Paper read before the Amer. Soc. for Testing Materials.) (20) June 27.

Four-Cylinder Compound Express Locomotive, Danish State Railways.* (11) June 28.

Steam Railway Motor Coach, East Indian Railway.* (12) June 28.

Solid Steel Wheels for Passenger Cars. George L. Fowler. (Paper read before the Master Car Builders' Assoc.) (15) June 28.

Consolidation Locomotive for the Chicago, Rock Island & Pacific.* (40) June 28.

Standard Specifications for Steel Rails. (Recommended by the Committee on Standard Specifications for Iron and Steel of the Amer. Soc. for Testing Materials.) (14) June 29; (15) July 5; (13) July 4.

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The Second Delaware & Hudson Gasoline Motor Car. (17) June 29.
Wireless Signaling System for Railroads.* (From *Western Electrician.*) (19) June 29.
The Railways of the Upper Congo.* Demetrius C. Boulger. (9) July.
The Manufacture of Steel Rails. James C. Bayles. (10) July.
New Method of Signalling in America.* (21) July.
Third Class Dining Cars; Great Central Railway.* (21) July.
Invalid Saloons; L. and North Western Railway.* (21) July; (40) July 12.
Taylor (British) "All Electric" Power Interlocking Plant.* (21) July.
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4-Cylinder Deglehn Compound 10-Wheel Locomotive, Paris-Orleans Railway.* (25) July.
Largest Passenger Locomotive, 4-6-2 Type, Pennsylvania Railroad.* (25) July.
Steel Postal Car, Harriman Lines.* (25) July.
Casting Shells and Hub and Side Liners in Driving Boxes, Lake Shore & Michigan Southern Railway.* (25) July.
Rail Corrugation.* Joseph A. Panton. (77) July.
Electric Lighting of Trains.* John Denham. (77) July.
Train-Lighting.* H. Henderson. (77) July.
Details of Derrick Car and Method of Work Adopted for Erecting a Railway Bridge.* (87) July.
Experiences with Limber and Stiff Rail Sections.* P. H. Dudley. (Abstract of paper read before the Amer. Soc. for Testing Materials.) (20) July 4; (41) June 28.
Express Passenger Engine, Midland Railway.* (12) July 5.
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New Dynamometer Car of the Pennsylvania Railroad.* (40) July 5; (18) July 6; (25) Aug.
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Arch Tubes and Brick Arches. (Abstracts of discussions read before Inter. Master Boiler Makers' Assoc.) (40) July 5.
The Power Plant of the Norfolk & Portsmouth Traction Co.* (14) July 6; (17) July 13.
How May Quality of Steel Rails be Improved? Henry M. Howe. (16) July 6.
A. C. Electrification on the Illinois Traction System.* John R. Hewitt. (17) July 6.
Standardization of Electric Railway Equipment. C. B. King. (Paper read before the Canadian St. Ry. Assoc.) (17) July 6.
Jacksonville Shops of the Seaboard Air Line Ry.* (18) July 6.
Tire Wear of Rolled Steel Wheels.* (18) July 6.
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Recently Constructed Italian Locomotives.* Chas. S. Lake. (47) July 6.
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Locomotive Smoke Prevention. John A. Hartman. (62) July 8.
Gravel Spreader Used on the Colorado River Levee Construction.* H. T. Cory, Assoc. M. Am. Soc. C. E. (13) July 11.
Compound Locomotive: Railways of the Grand Duchy of Oldenbourg.* (11) July 12; (15) July 19.
New Station, Yard and Terminal Facilities of the Harriman Lines at Salt Lake City.* (15) July 12.
The Railroads of Mexico. Erdis G. Robinson. (15) Serial beginning July 12.
Progress of the Pennsylvania Tunnels under Manhattan Island.* (15) July 12.
The Stratford Power Station of the Great Eastern Railway.* (26) July 12.
Dry Battery (Railway Signalling). U. J. Fry. (40) July 12.
The Fortieth St. Track Elevation of the Chicago Junction Ry.* (14) July 13.
Some Effects of the Recent Earthquake in Jamaica Upon Railway Structures. J. Mark Fletcher, Assoc. M. Am. Soc. C. E. (14) July 13.
Key Route Interlocking Plants.* (17) July 13.*
The Plans for the Boston & Eastern Electric Railroad.* (17) July 13.
Arc Lamps for Railway Car Illumination; Their Distribution and Characteristics.* Alfred L. Eustice. (27) July 13.
A Remarkable Locomotive.* Chas. S. Lake. (47) July 13.
Results of Use of Different Valve Gears on Locomotives. (Abstract of Report of Committee to Amer. Ry. Master Mechanics' Assoc.) (47) July 13.
New York, Auburn & Lansing Railroad.* (72) July 13.
Cars for City Service. T. J. Nicholl. (72) July 13.
The Longest Narrow-Gauge Light Railway in the World.* (11) July 19.
The Pennsylvania New Terminal, New York.* (12) Serial beginning July 19.
New Passenger Station at Evansville for the Evansville & Terre Haute.* (15) July 19.

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New Top-Mast Motor Signal.* (15) July 19.
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The Nine-Mile Power Station of the Spokane & Inland Empire Railway.* H. Cole Estep. (14) July 20.
New Turbine Generating Station of the Illinois Traction System at Peoria, Ill.* (17) July 20.
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The Work of the "Experiments" on the London and Northwestern Railway. (11) July 26.
Increase in the Weight of Locomotives.* (15) July 26.
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Early Years of the Philadelphia & Reading.* C. H. Caruthers. (15) July 26.
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The Maximus Brake.* (15) Aug. 2.
The Trans-Andine Railroads.* Lewis R. Freeman. (15) Aug. 2.
A Balanced Compound Locomotive for the Italian State Railroads.* (15) Aug. 2.
New Union Station for Three Roads at Waco, Tex.* (15) Aug. 2.
Reinforced Concrete Structures on the Kansas City Outer Belt & Electric Railroad.* Walter W. Colpitts, M. Am. Soc. C. E. (40) Aug. 2.
Tests of the Live Load on Driving Springs.* Charles A. Howard. (40) Aug. 2.
The Bothwell Locomotive.* (40) Aug. 2; (18) Aug. 3.
Method of Excavating Rock in Large Masses (Grand Trunk Pacific R. R.). George C. McFarlane. (16) Aug. 3.
Rack-rail Haulage in Coal Mines.* George E. Lynch. (16) Aug. 3.
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A New Mountain Locomotive.* (Translated from *La Nature.*) (19) Aug. 3.
The Inauguration of the New Haven Railroad Electric Service.* (46) Aug. 3.
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Nouveau Dispositif pour la Manœuvre Electrique de Signaux et des Aiguilles en Service à la Gare de Courcelles-Ceinture à Paris.* (38) Apr.

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La Conservation des Traverses de Chemins de Fer, Pénétration de la Chaleur dans le Bois. (33) Apr. 27.
Les Oscillations du Matériel dues au Matériel lui-même et les Grandes Vitesses des Chemins de Fer.* Georges Marié. (38) Serial beginning May.
La Reconstruction de la Gare de Valenciennes.* Cossmann and E. Despons. (38) Serial beginning May.
Mesure des Déplacements Relatifs des Rails Appareil Reitler.* Mesnager. (33) May 4.
Chemin de Fer Electrique Monophasé de la Vallée du Brembo (Lombardie).* P. Chignaterie. (33) June 22.
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Le Freinage des Trains à Grand Vitesse: Nouveau Type de Frein, Système Maximus.* A. Boyer-Guillon. (33) July 27.
L'Electrification du New-York Central Railroad dans la Baulieue de New-York.* (33) July 27.
Der Talübergang der Westerwaldquerbahn bei Westerburg.* Wolpert. (49) Vol. 7-9, 1907.
Die Eisenbahnbetriebsmittel auf der Ausstellung in Mailand 1906.* Metzeltin. (48) Serial beginning May 4.
Die Maschinellen Anlagen beim Bau des Tauerntunnels.* K. Brabbée. (48) May 25; (53) Serial beginning June 7.
Der Berner Alpendurchstich (Lötschbirgbahn).* Fritz Hromatka. (53) May 31.
Das Richten von Eisenbahnschienen im Kalten und Warmen Zustande.* S. von Schukowski. (50) June 5.
Die Einführung des Elektrischen Zugbetriebes auf den Berliner Stadt-, Ring- und Vorortbahnen. W. Reichel. (48) Serial beginning June 22.
Der Antriebvorgang bei Lokomotiven.* J. Jahn. (48) Serial beginning July 6.

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The Air of the New York Subway Prior to 1906.* George A. Soper. (7) Mar.
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The Successful Operation of Trail Cars in Denver.* (72) May 4.
The Brighton Beach Improvement of the Brooklyn Heights R. R.* (14) May 18; (17) May 11.
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New Rails for the Chicago Street Railways.* (Specifications.) (13) May 23.
The Charing Cross, Euston & Hampstead Railway.* (73) May 31.
Some Notes on the Breaking of Trolley Wires. P. S. Sheardown. (Abstract.) (77) June.
Remote Control High-Tension Switchgear.* Frank Walker. (Abstract.) (77) June.
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Rapid Transit in Boston and Vicinity.* (72) June 1.
Constructing Elevated Railroad Foundations over a Large Sewer.* (14) June 8.
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New Shops and Shop Practice of the Omaha & Council Bluffs Street Railway Company.* (17) June 22.
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Grade Correction and Pile Foundations in the East River Tunnel of the New York Rapid Transit Subway.* (13) June 27.
Platform Arrangements at Grand Central.* (17) June 29.
Shops and Shop Practice of the Los Angeles Railway.* (72) July 6.
An Official Report on the Condition of the East River Tunnel. Nelson P. Lewis, M. Am. Soc. C. E. (13) July 11; (14) July 13.
Notes on Tramway Rail Wear.* C. F. Wike. (Paper read before the Incorporated Assoc. of Municipal and County Engrs.) (22) July 12.
Sixty-Ninth Street Terminal of the Philadelphia Rapid Transit Co.* (18) July 13.
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The Saint-Michel Station of the Paris Metropolitan.* (Translated from *La Nature.*) (19) July 20.
The Operating Costs and Revenue of Urban Railways. Gerard B. Werner. (9) Aug.

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Lowering the Grade of a Tunnel at Kansas City, Mo. (Metropolitan Street Ry.)* W. M. Archibald. (Abstract of paper read before the Eng. Soc. of the South.) (13) Aug. 1.

Ergebnisse der Konkurrenzfahrten mit Motorwagen und Leichten Lokomotiven auf der Vorortelinie der Wiener Stadtbahn. (53) July 5.

Sanitary.

The Efficiency of the Shone System of Pumping.* Charles Leslie Cox. (63) Vol. 168.

Big Four Sanitary Sewage Disposal System.* (86) May 3.

The Pollution of New York Harbor. George C. Whipple. (Abstract of paper read before the N. Y. County Homeopathic Medical Assoc.) (14) May 25; (13) May 23.

The Admission of Trade Wastes into the Sewers of Reading, Pa. (14) May 25.

Street Cleaning in the Central Business District of Chicago.* (14) May 25.

The Health of Employees in the New York Subway. George A. Soper. (7) June.

English, German and Swiss Destructors Plants.* Frank C. Perkins. (60) June.

Data for Heating Calculations. Wm. Kent. (Paper read before the Nat. Assoc. of Master Steam and Hot Water Fitters.) (70) Serial beginning June.

Heating and Ventilating of the Title Guarantee Trust Building, New York.* (14) June 1.

The Comparative Disposition of Organic Matter by Sand, Contact and Sprinkling Filters. H. W. Clark. (Abstract of paper read before the Amer. Pub. Health Assoc.) (13) June 6.

Use of Gas from a Hygienic Standpoint. Vivian B. Lewes. (66) June 25; (24) Aug. 5.

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Vol. XXXIII. AUGUST, 1907. No. 6.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

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REINFORCED CONCRETE TOWERS.

By D. W. Krellwitz, Jun. Am. Soc. C. E.

To be Presented October 2d, 1907.

Electrical energy is now being delivered by transmission lines to cities many miles distant from its source. The wires carrying the current are supported on towers which must conform to the requirements of navigation when rivers and canals are crossed, that is:

"There must be ample overhead clearance from the water to the nearest point of the transmission wires, so that vessels with high masts can pass under the wires." (Fig. 1.)

This paper describes the reinforced concrete towers, built for The Lincoln Light and Power Company, on each side of the old Welland Canal, in the Province of Ontario, to transmit current from the transformer building to St. Catharines, Ontario, Canada.

These towers are 150 ft. high, 142 ft. being above ground. They are 11 in. square at the top and 31 in. square at the bottom, with chamfered corners, and are provided with foot steps and rungs. Each tower carries sixteen No. 1 bare copper wires on glass insulators. The cross-arms are 3½ by 4 in., and are 10 ft. long, and beneath them there is a working platform about 10 ft. long and 5

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ft. wide. The span over the canal is 76 ft., but adjacent to this span there is a span of about 300 ft. On one of the towers the wires run vertically, being fastened to two frames, 42 and 82 ft., respectively, from the top. At the top of this tower there is a heavy pull parallel to the line, which at this point makes a right-angled turn.

The collapse of a tower on a transmission line, caused by a storm, would be a very serious matter, and would be likely to cause lawsuits, the loss of light and power customers, and, perhaps, loss of life, on account of the dangerous currents.

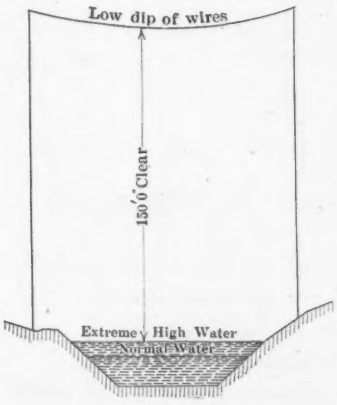


FIG. 1.

These towers have been designed to withstand wind pressures of 30 lb. per sq. ft. on flat surfaces, and 15 lb. per sq. ft. on cylindrical surfaces. A liberal assumption was made by calculating the exposed surface of the wire as its diameter plus a coating of ice ¾ in. thick multiplied by the span. As the greatest wind pressures in that part of the country have never exceeded an average of 30 lb. per sq. ft. on large areas, it is reasonable to believe that these towers are absolutely safe.

The following conditions were observed in designing the towers:

Case I.—Tower, without wires, and not guyed; to withstand a pull of 2 000 lb. at the top;

Case II.—Guyed tower; to withstand full wind pressure plus pulls transverse to the line, due to the wires;

Case III.—In case of the breakage of all the line wires—for 300 ft. span—the total pull to be taken on the guyed tower plus full wind pressure on the tower.

The calculations are based on the following assumptions:

First.—The section plane before bending remains plane after bending; that is, the stress of any fiber is proportional to its distance from the neutral axis (Fig. 2).

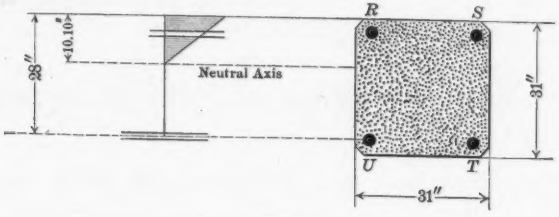


FIG. 2.

Second.—The applied forces are perpendicular to the plane of the neutral axis.

Third.—The tensile strength of the concrete is neglected.

Fourth.—There are no initial strains.

$\frac{\text{Modulus of elasticity of steel}}{\text{Modulus of elasticity of concrete}} =$	15
Ratio of cross-section of steel in tension to cross-section of beam above this steel...	0.01129
Ratio of cross-section of steel in compression to cross-section of beam above the steel in tension	0.01129
Compressive stress in the extreme fiber of concrete.....	600 lb. per sq in.
Tensile stress in steel.....	16 000 lb. " " "
Compressive stress in steel.....	6 350 lb. " " "
Ratio of depth of steel in compression to depth of steel in tension.....	0.10714
Depth of steel in tension.....	28 in.

Case I.—The bending moment is $2\,000 \times 142.0 = 284\,000$ ft-lb. The distance from the compressive surface to the neutral axis, when the maximum allowable bending moment is applied, is:

$$\left[\sqrt{2 \times 15 \times (0.01129 + 0.01129 \times 0.10714) + 15^2 \times (0.01129 + 0.01129)^2} - 15 \times (0.01129 + 0.01129)\right] \times 28 = 10.108 \text{ in.}$$

The ratio of depth of neutral axis to depth of steel in tension is..... 0.3610

The moment of resistance is:

Taking moments about the center of compression in concrete,

$$\frac{31 \times 28^2 \times \left[16\,000 \times 0.01129 \times \left(1 - \frac{0.361}{3}\right) + 6\,350 \times 0.01129 \times \left(\frac{0.361}{3} - 0.10714\right)\right]}{12} = 323\,700 \text{ ft-lb.}$$

Taking moments about the center of compression stress in the steel,

$$\frac{31 \times 28^2 \times \left[16\,000 \times 0.01129 \times (1 - 0.10714) - \frac{600 \times 0.361}{2} \times \left(\frac{0.361}{3} - 0.10714\right)\right]}{12} = 323\,700 \text{ ft-lb.}$$

The compressive stress in the extreme fiber of the concrete, due to bending, is:

$$\frac{284\,000 \times 12}{31 \times 28^2 \times \left[\frac{0.361}{2} \times \left(1 - \frac{0.361}{3}\right) + \frac{15 \times 0.01129 \times (0.361 - 0.10714) \times (1 - 0.10714)}{0.361}\right]} = 529 \text{ lb. per sq. in.}$$

The compressive stress in the steel, due to bending, is:

$$\frac{284\,000 \times 12}{31 \times 28^2 \times \left[0.01129 \times \left(\frac{1 - 0.361}{0.361 - 0.10714}\right) \times \left(1 - \frac{0.361}{3}\right) + 0.01129 \times \left(\frac{0.361}{3} - 0.10714\right)\right]} = 5\,578 \text{ lb. per sq. in.}$$

The direct compressive stress in the concrete, caused by the dead load of the tower above the point of maximum stress, due to bending, is:

$$\frac{63\,300}{(19.6 \times 15) + (31^2 - 19.6)} = 51 \text{ lb. per sq. in.}$$

19.6 sq. in. = area of four rods

63 300 lb. = dead load.

The direct compressive stress in the steel, caused by the dead load of the tower above the point of maximum stress, due to bending, is:

$$\frac{63\,300}{19.6 + \frac{31^2 - 19.6}{15}} = 769 \text{ lb. per sq. in.}$$

The combined compressive stress in the extreme fiber of the concrete is:

$$529 + 51 = 580 \text{ lb. per sq. in.}$$

The combined compressive stress in the steel is:

$$5\,578 + 769 = 6\,347 \text{ lb. per sq. in.}$$

Case II.—

Diameter of wire	0.3 in.
Thickness of ice coating	0.75 "
Total	1.05 in. = 0.087 ft.

Wind pressure per linear foot of wire $= 0.087 \times 15 = 1.3$ lb.

Weight of wire per foot	0.27 lb.
Weight of ice load per foot	0.324 "
Total	0.594 lb.

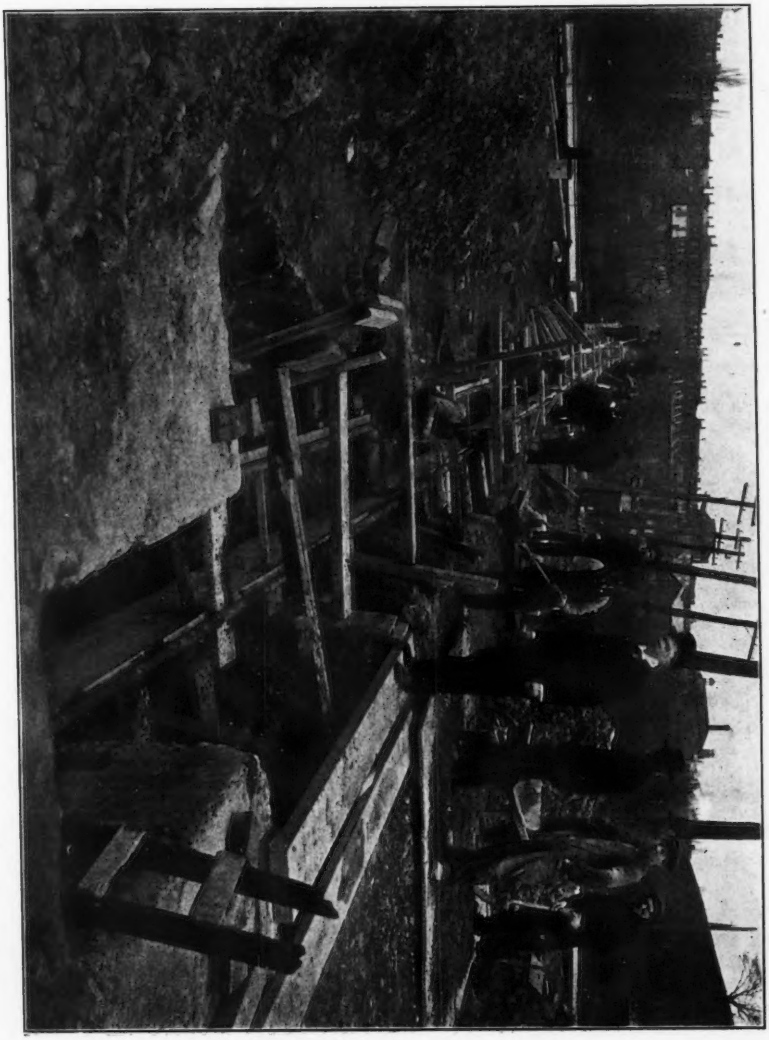
The resultant force, normal to the line, is:

$$\sqrt{0.594^2 + 1.3^2} = 1.43 \text{ lb. per ft. of wire;}$$

and the total resultant force is:

$$\left(\frac{300 \text{ ft. span}}{2} + \frac{76 \text{ ft. span}}{2} \times 1.43\right) \times 16 \text{ wires} = 4\,300 \text{ lb.}$$

Vertical force on tower, due to resultant force	5 000 lb.
Weight of cross-arms and platform	600 "
Dead load of tower above the point of maximum fiber stress due to bending	63 300 "
Total	68 900 lb.



Mrdll

Area of four steel rods = 19.6 sq. in.

The fiber stress in the concrete, due to direct compression, is:

$$\frac{68\,900}{(19.6 \times 15) + (31^2 - 19.6)} = 56 \text{ lb. per sq. in.}$$

In calculating the fiber stress due to bending, caused by wind pressure, the towers are considered as held at the top with steel guys and fixed at the base (Fig. 3).

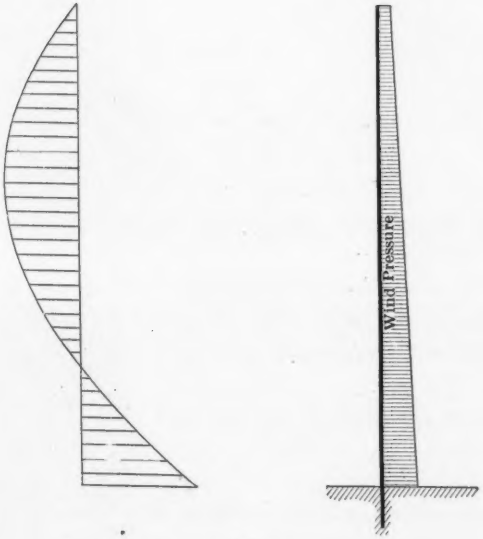


FIG. 3.

The wind pressure is:

247 sq. ft. $\times$ 30 lb. = 7 410 lb.

and the maximum moment due to wind is 118 200 ft-lb.

The fiber stress due to direct compression is	56 lb. per sq. in.
The fiber stress compression due to bending is	222 " " " "
Total compression in the concrete.	278 lb. per sq. in.

Case III.—

The area of one wire is 0.07 sq. in., and, in case all the line wires break, the pull is:

$$0.07 \times 16 \times 60\,000 = 67\,200 \text{ lb.}$$

The vertical force on the tower is.....	50 000 lb.
The weight of the cross-arms and platform is	600 "
The dead load of the tower, above the point of maximum fiber stress, due to bending, is	63 300 "
Total.....	113 900 lb.

The fiber stress in the concrete due to direct compression is:

$$\frac{113\,900}{(19.6 \times 15) + (31^2 - 19.6)} = 92 \text{ lb. per sq. in.}$$

The maximum moment due to wind is the same as for Case II, or 118 200 ft-lb.

The fiber stress due to bending is...	222 lb. per sq in.
The fiber stress in the concrete due to direct compression is.....	92 " " " "
The total compression in the concrete is	314 lb. per sq in.

The unsupported length of tower is fifty-two times the maximum width and seventy-seven times the average width. It would be of interest to know what "verified formula" would give the permissible strains per square inch for long reinforced concrete compression members.

A square cross-section, with four corner rods (*R*, *S*, *T*, and *U*), was chosen for the towers, as such an arrangement was more economical in steel than any other, each rod doing double duty. For instance, if the tower were strained about one axis, the rods, *R* and *S*, being in tension, if strained about another axis at right angles to the first, the rods, *S* and *T*, being in tension, the rod, *S*, would be doing double duty.

PLATE LXVII.
PAPERS, AM. SOC. C. E.
AUGUST, 1907.
KRELLWITZ ON
REINFORCED CONCRETE TOWERS.

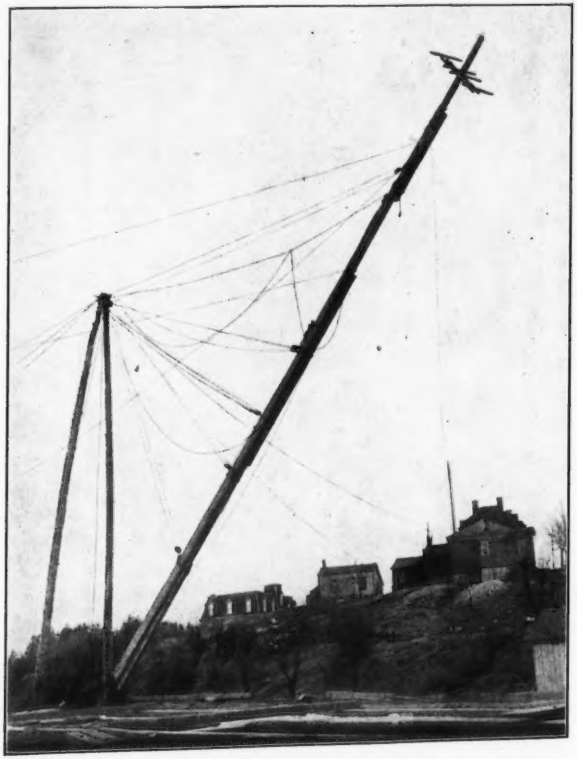


FIG. 1.—SHEARS FOR ERECTING TOWERS.



FIG. 2.—REINFORCED CONCRETE TOWERS.

The tower at the right-angled turn of the line stood a remarkable test while changing the guys. On August 2d, 1906, it withstood the pull (tension in wires) parallel to the line without any guy to resist this pull. The maximum deflection at the top was about 2 ft. Not having the necessary apparatus at this time, the pull could not be ascertained. There were no visible cracks, nor was there any movement at the base. On another transmission line, however, a 59-ft. tower showed movement at the base, because the base was not large enough.

The base of each tower was constructed with an opening on one side so that the foot of the tower could not slide horizontally during erection. The finished base is a cube of concrete 10 ft. on each side, and having 8 ft. of the tower within it.

The moulds for the towers were inclined from the base upward, as shown by Plate LXVI, because the saving in erection more than offset the extra cost of excavating. While setting up the bottom sections on blocking, great care was taken to avoid unequal settlement. The side sections were set plumb, and braced properly to withstand the lateral pressures. The moulds were wet (except in freezing weather) before placing the concrete. Cores were set to wooden templets near the top for the holes required for bolting the cross-arms. Holes, 2 in. in diameter, were bored in the top side sections so that the bent ends of the foot steps would pass through when the moulds were removed.

The concrete for the towers was composed of 1 part of Portland cement and 5 parts of the very best gravel, with sand, of which 36% was "fine," having passed through a sieve of 0.2-in. mesh, and 64% was "coarse," being that which was retained in the sieve. The gravel, sand, and cement were first thrown together and turned over twice; water was supplied in pails, and the mixture was turned a sufficient number of times to produce a loose concrete of uniform color and consistency. Great care was taken in mixing the concrete and also in placing the steel and concrete.

At intervals of 20 in., foot steps were embedded in the upper part, and ladder rungs in the lower part, of each tower.

Two wooden shear legs, Fig. 1, Plate LXVII, with necessary steel back and side guys and steel hoisting tackle, were used in erecting the towers. Careful study was made during erection

as to the proper positions of the hitches, in order to avoid any excessive deflections which might be caused by concentrated pulls during erection.

The last tower was moulded on April 17th, 1906, and the sides of the mould were removed two days later. Its erection was commenced on May 25th, 1906, or 38 days after moulding; smaller towers, however, have been erected successfully 14 days after moulding.

It is believed that these towers are the highest monoliths in existence at the present time, and it may be interesting to state that during their erection no men were injured in any way.

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REINFORCED CONCRETE PIPE FOR CARRYING WATER UNDER PRESSURE.

By Chester Wason Smith, Assoc. M. Am. Soc. C. E.

To be Presented October 2d, 1907.

This paper describes the construction of about 6 000 ft. of reinforced concrete pipe intended to carry water under pressure; and also gives the results attained and some figures as to the cost. The work was in charge of the writer.

History and Conditions.

A prominent feature of the Salt River project, in process of construction in Arizona by the United States Reclamation Service, is a canal 19 miles long, having a capacity of 250 cu. ft. per sec. This canal is to furnish power to build the Roosevelt Dam, run the cement mill furnishing the cement therefor, and, later, pump water for additional irrigation in the vicinity of Phœnix.

At Livingston, about 6 miles below the canal intake, the canal crosses Pinto Creek, at that point nearly ½ mile wide, and about 25 ft. below the canal grade.

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The crossing of Cottonwood Cañon is 2½ miles above the Roosevelt Dam, which is at the lower end of the canal. The crossing is 250 ft. wide on the bottom and 75 ft. below the canal grade.

Pinto Creek has a water-shed of 190 sq. miles. At the canal crossing its grade is about 1%, and the material there is sand with a little gravel and small cobbles.

At the Cottonwood Crossing the cañon has a water-shed of about 4 sq. miles. The grade of the creek is about 4%, and the material is boulders and gravel.

Both creeks are dry nearly all the time, except for a small underflow; but they are subject to occasional large and sudden run-

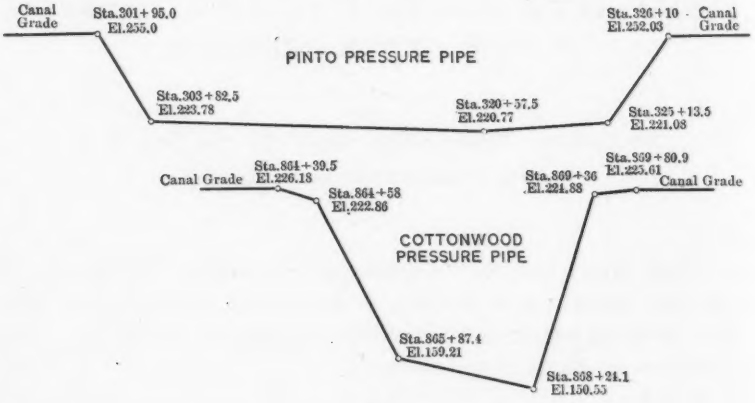


FIG. 1.

offs, characteristic of the flow from mountainous water-sheds which lack vegetation.

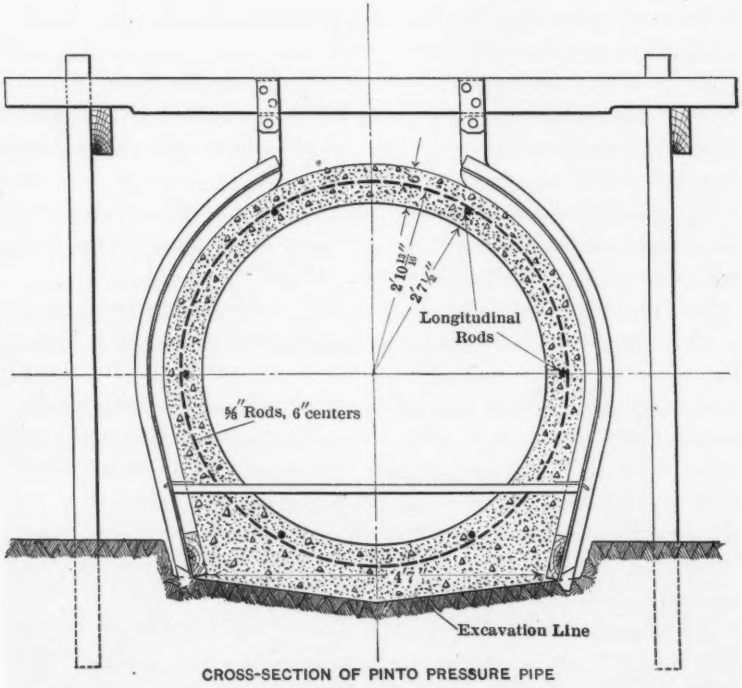
It was decided to make each crossing with two lines of reinforced concrete pipe, circular inside, and 5 ft. 3 in. in diameter, giving the Pinto Crossing an effective grade of 2.97 ft. in 2 415 ft., and the Cottonwood Crossing 0.57 ft. in 541.4 ft. The pipes are buried under the creek, their tops being from 2 to 5 ft. below its bed.

Fig. 1 shows the profiles of the pipes at each crossing, the water level in the canal at full capacity being 5½ ft. above the canal grades noted.

Fig. 2 is a cross-section of the Pinto pipe. The concrete in the Cottonwood pipe is 7 in. thick; there are ten longitudinal rods, and the spacing of the rings is 3 in. from center to center.

The reinforcement, longitudinal and transverse, consists of $\frac{5}{8}$-in. steel rods, having an ultimate strength of 62 000 lb. and an elastic limit of 30 000 lb. per sq. in.

At Pinto Creek there was excellent sand and gravel at all points in the excavation; the water used in the concrete for the first line of pipe was pumped from the trench (the trench intercepting the



CROSS-SECTION OF PINTO PRESSURE PIPE

FIG. 2.

underflow of the creek), and the first pipe was tapped to furnish the water used in building the second one.

At Cottonwood the sand and gravel, and nearly all the water, were hauled about $\frac{3}{4}$ mile from Salt River.

The concrete was composed of 1 part of Portland cement, $2\frac{1}{2}$ parts of sand, and 4 parts of rather fine gravel, and was mixed by

hand, quite wet, on platforms of boards about 150 ft. apart along the trench.

The first length of 200 or 300 ft. of pipe was made in June, 1905, with cement purchased from the Portland Cement Company, of Denver, Colo. This was an average Portland cement. A progress of 120 ft. per 24 hours was easily attained with a comparatively raw gang.

Afterward, the cement used was the product of the mill installed and operated by the Reclamation Service to furnish cement for building the Roosevelt Dam.

During the summer and fall of 1905 nearly the entire output of this mill was required by contractors for various other work along the canal, and work on the pipe was frequently interrupted for considerable periods of time.

On account of lack of cement, also, on account of several floods, the completion of the first line of pipe across Pinto Creek was delayed until the middle of November, 1905.

As one line would carry all the water needed to furnish power for building the dam, and as power was required as soon as possible, the forms were then moved to Cottonwood, where the two lines were constructed. In March, 1906, the construction of the second line at Pinto was started, but, owing to various delays not connected with the construction, this line was not completed until about August 1st. Much of the time during the construction of both Pinto pipes the temperature was more than 100° fahr. The Cottonwood pipes were constructed entirely in winter, when the temperature was between 35 and 55 degrees.

The cement manufactured at Roosevelt, while excellent as regards strength and soundness, has been extremely slow setting. An average sample would test about as follows:

Fineness: 95% passed the 100-mesh sieve and 76% passed the 200-mesh.

Setting: initial, 4½ hours; final, 12 hours.

Tensile strength: neat, 7 days, 450 lb.; 28 days, 550 lb.; 3 months, 625 lb.; 1 part cement to 3 parts standard sand, 7 days, 100 lb.; 28 days, 200 lb.; 3 months, 260 lb.

A 6-in. concrete cube was made of the materials used in the pipe, except that the proportions were by weight, 1 cement, 2½ sand,

and 4½ gravel, mixed with about the same proportion of water. The batch from which the cube was made was composed of 1 200 g. of cement (of which only 64% passed the 200-mesh sieve), 3 000 g. of sand, 5 400 g. of gravel and 720 g. of water. This cube, after having set for 3 months in water, was crushed at 59 180 lb., or 1 644 lb. per sq. in. This rather low result was due partly to the coarseness of the cement, and partly to the fact that such a wet concrete was slow in attaining its strength.*

With such cement, and 70 lin. ft. of upper stationary plates, it was found that not more than 70 ft. of pipe could be made in 24 hours without getting into difficulties when the plates were removed, as patches of concrete would fall out or peel off with them. With cooler weather, the difficulties increased; accordingly, on the completion of the first line across Pinto Creek, the idea of continuous work was abandoned, and work on the Cottonwood lines and the remaining Pinto line was done with one 8-hour shift per day.

On the Cottonwood lines, built in December and January, it was found that only 24 ft. of pipe per day could be built, thus allowing 3 days for the concrete to harden before removing the plates.

The second Pinto line, constructed in warmer weather, was built at the rate of 40 ft. per day.

Movable Form.

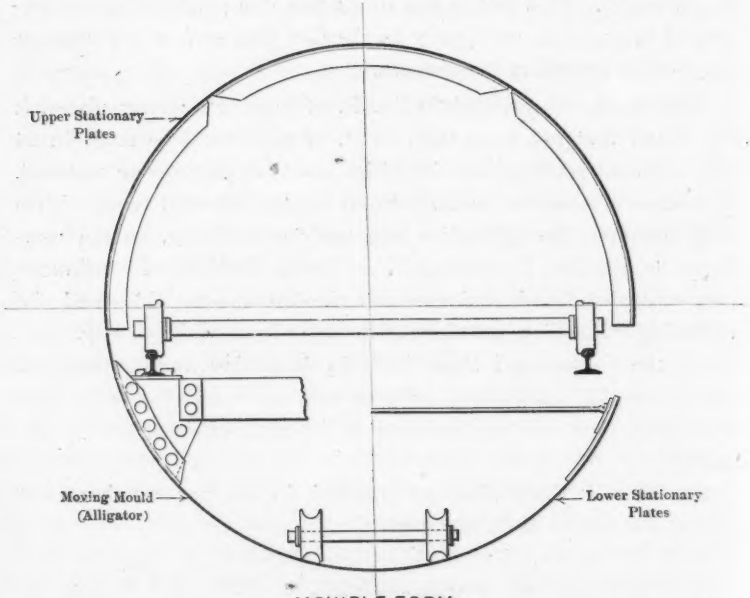
It was considered desirable to work continuously on the pipe, with three 8-hour shifts, in order to avoid, as far as possible, transverse joints, and consequent probable opening betwen the work of different days.

To facilitate continuous work, a movable form was designed and introduced on the work by F. Teichman, M. Am. Soc. C. E., Designing Engineer in the Reclamation Service.

Briefly described, the form, as shown in Figs. 3 and 4, and the photographs on Plate LXVIII, is as follows: A steel semi-cylinder, called "the alligator," forms the inside of the lower half of the pipe; this piece is pulled along by a cable from a horse-power whim

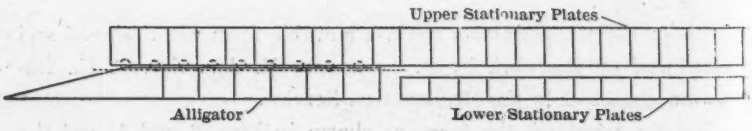
* Cubes since made from batches of concrete being put into the Roosevelt Dam have been crushed, at 3 months, as high as from 89 000 to 103 000 lb. per sq. in. This concrete was composed of 1 part of cement, 2½ parts of sand made by crushing dolomite limestone, and 4 parts of crushed sandstone, mixed to the same degree of wetness.

in the trench ahead. It is kept to line and grade by a steering apparatus, extending about 8 ft. in front of its nose, and either rolling or sliding on a light wooden track previously laid. The inner form for the upper half of the pipe consists of steel semi-



MOVABLE FORM
FOR BUILDING REINFORCED CONCRETE PRESSURE PIPE

FIG. 3.



PART OF MOVABLE FORM FOR BUILDING REINFORCED CONCRETE PRESSURE PIPE

FIG. 4.

cylinders in 2-ft. lengths, each in three pieces, that is, hinged at two points, to facilitate moving and erection.

These upper stationary plates are bolted together, end to end, making a continuous form, from the front end, where concrete is



FIG. 1.—THE "ALLIGATOR," USED IN BUILDING REINFORCED CONCRETE PRESSURE PIPE.

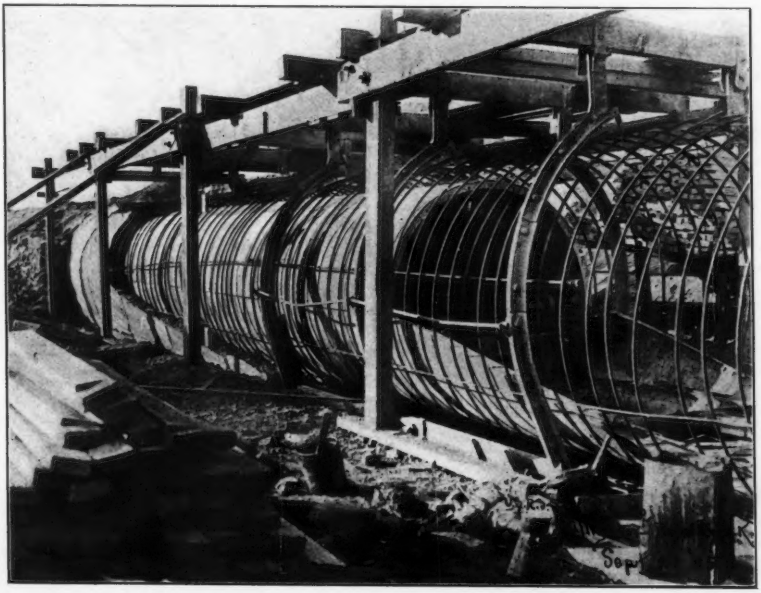


FIG. 2.—THE "ALLIGATOR," USED IN BUILDING REINFORCED CONCRETE PRESSURE PIPE.

going in, to the rear end, where the concrete has set sufficiently to permit their removal; they are supported by rollers on a track which is part of the alligator, the alligator thus rolling out from under the upper stationary plates. Immediately behind the alligator are introduced lower stationary plates in 2-ft. lengths, one plate being inserted as often as a length of 2 ft. of invert is exposed. On the withdrawal of the alligator, an upper stationary plate is thus supported by the plate ahead on the alligator and a plate behind on a lower plate, until the insertion of its lower plate. Upper and lower plates are removed at the rear end and sent ahead on a small truck hauled back and forth with a rope, on a track in the bottom of the lower plates and alligator.

The outside lagging was of 2½-in. lumber in narrow pieces, about 5½ ft. long, laid on the same slope as the nose of the alligator (1 in 4) between iron ribs hung from a wooden superstructure. This superstructure also carried the runways for wheeling out the concrete.

Construction.

The rings were bent to the desired circumference by a small bending machine. The ends were not upset or welded, but merely lapped about 15 in. and tied with baling wire; they were also wired at each crossing with each longitudinal rod, in order to hold them in place while the concrete was being put in.

The concrete was made with fine gravel, and mixed quite wet, in order to be worked into the narrow space between the reinforcement and the forms completely and easily. It was brought out in wheel-barrows on top of the superstructure and dumped wherever desired along the working face, that is, from the bottom of the pipe at the nose of the alligator, back on the 1 in 4 slope to the top of the pipe at the third or fourth upper stationary plate. One or two small chutes were found desirable in connection with the dumping.

Two men on each side, provided with small wooden paddles, churned the concrete to make certain that all voids were filled, and to prevent any nesting of the gravel. These men also introduced the outside lagging, that operation and the moving ahead of the alligator being regulated so that the working face was from

0 to 8 or 10 in. below the forms. On stopping work for the night, or if the continuous operation was interrupted for any reason, the blocking off was done at right angles to the axis of the pipe. This was done by stuffing sand bags between the inner and outer forms. This was more convenient than the use of a wooden stop, and afforded a rougher surface with which to bond when work was resumed.

The pipe was wet down on the outside for about a week after completion, and, as far as possible, the back-filling was kept up to the watering.

Some smoothing and pointing was necessary inside the pipe, and one or two brush coats of neat Portland-cement grout were applied; but no plaster coat was put on, nor was any water-proofing material used.

Difficulties.

It was difficult to overcome the tendency of the alligator to twist and travel off line or grade, and the steering apparatus was designed to prevent this, it not having been a part of the original form. It did much toward correcting the eccentricities in the travel of the alligator, but, at best, much depended upon constant watchfulness, and it was found necessary to stop work once in 8 or 10 days in order to level and straighten it out.

It is very doubtful if a uniform thickness could have been attained, even had an attempt been made to shift and adjust the outside forms and the reinforcement to correspond with the movements of the alligator. With this form, the minimum thickness will be at least 1½ in. less than the average thickness.

Considerable trouble was caused by the concrete peeling off with the upper stationary plates; particularly—in fact almost solely—with the middle segment of the plate. Large patches, often an inch or more in depth, would come off with the plate.

To overcome this, various schemes were tried; soft soap or crude oil was applied to the plates immeditely before covering them with concrete; particular care was taken to allow no spatterings of concrete to accumulate on the plate and dry out in advance of covering it with the mass of concrete; variations in the quantities of water in the concrete were also tried. Experience seemed to



FIG. 1.—THE CONSTRUCTION OF THE PINTO PRESSURE PIPE.



FIG. 2.—THE CONSTRUCTION OF THE COTTONWOOD PRESSURE PIPE.
(The inclines were built with wooden forms, concrete being run down in chutes from above.)

show that the only satisfactory remedy was to allow the concrete to set more thoroughly before removing the plates; if given sufficient time, a perfect surface was obtained. No special precautions were taken to guard against transverse joints between the work of different days, but, when an end was to be left for more than one day before resuming work, extra longitudinal rods were inserted, extending about 2 ft. into the work on each side of the joint.

Results.

Transverse Joints.—On the first Pinto line, where there were few interruptions to continuous work, and where a portion of it was built in comparatively cool weather, there were very few transverse joints worthy of mention, and none requiring any treatment. On the two Cottonwood lines, built in the coldest weather, none has been observed.

On the second Pinto line, built entirely during the hottest weather, with about fifty interruptions to continuous work, and first filled in cold weather, it was to be expected that the transverse joints would be larger in number and size. At about forty of them there was a perceptible crack; of the forty cracks about twenty-five were $\frac{1}{16}$ in. or more in width, and were repaired, some of them before the pipe was first filled, and the remainder afterward. In general, they were more frequent and pronounced in one or two sections where the watering of the pipe was discontinued before the back-filling was done.

Longitudinal Cracks.—When the pipes were put in service, some longitudinal cracks, from $\frac{1}{16}$ to $\frac{3}{16}$ in. in width, developed (see leakage tests in Table 2), and at first various possible causes or contributary causes were assigned to them:

First, they were ascribed to the water hammer, which was considerable when the pipes were being filled.

Second, it was thought that the excavation of the trench for the second line of pipe (10 ft. from center to center of the first line) threw an eccentric load on the first pipe. This undoubtedly had an effect on the cracks in the first Pinto pipe, and, as soon as it was observed, the remainder of the second pipe was moved 10 ft. further away.

Third, the cracks being invariably in the top of the pipe, and within a few inches of the center, it was thought that possibly the laps in the reinforcing rings had been put in on that line, and that the rods, or some of them, had parted from the concrete. Enough evidence was at hand, however, to show that the laps had been properly staggered. If such had been the cause, a longitudinal crack developing in a few hours to 200 or 300 ft. long, would have resulted in the total failure of that portion of the pipe.

The true reason is undoubtedly as follows: The concrete shrank in the process of setting; this was resisted by the steel rings, thus producing a condition in which the steel was in compression and the concrete in tension. Therefore, on filling the pipe, the concrete took the entire load until it failed, and then the steel took the load.

That the cracks were invariably in the top of the pipe was probably due to the fact that the lower third of the pipe was in sand kept wet by the underflow; in effect, this lower part set under water, and the shrinkage was relatively small.

A careful inspection of the inside of the pipe showed that, wherever the crack occurred, the single large crack was the only one; and at points where there was no large crack, the upper two-thirds of the inside surface showed a network of very minute cracks.

These were from 1 to 4 or 5 in. apart, and generally so fine that they could have had but a very insignificant effect on the leakage, and, in fact, they were only detected by the presence of a minute line of the finest sediment which was deposited at the crack without passing through.

The writer is of the opinion that the minute cracks existed previous to the filling of the pipe, consequently, that at those places the steel carried the load immediately upon its application; however, there is no way to verify this. Repairs were made (on the inside of the pipe) in the following manner: each crack was cut out to a depth of about 2 in. and as narrow as possible, 1 in. of oakum was then caulked in tightly, and over that, the joint was pointed with stiff mortar. In addition, grout was run into the crack from the outside.

Several observations have been made for the purpose of determining the value of n, in Kutter's formula, and, while the en-

tire series contemplated has not been made, the observations on the Cottonwood pipes, thus far, show that $n = 0.012$, approximately.

In considering the results of the leakage tests, it should be borne in mind that Salt River carries considerable sediment. Observations at Roosevelt have shown that the quantity varies from a mere trace up to 4 or 5 per cent. Practically, the water is never without some sediment, but the maximum occurs only during the highest floods; the average would be between one-fourth and one-half of 1 per cent.

Between Roosevelt and the canal intake, considerable quantities of the sediment, at ordinary stages of the river, settle in the flat reaches, so that at the intake, while the maximum quantity of sediment is not more than at Roosevelt, the average is undoubtedly greater.

At several points along the canal there are mud boxes from which more or less sediment is occasionally sluiced, but the canal carries a larger percentage of sediment than the river, except when the latter is in flood.

Cost.

The figures in Table 1, as to the cost of two sections of the second Pinto pipe, show the labor cost only, and do not include engineering, first cost of forms, cement, reinforcement, or grading.

TABLE 1.—Cost of Pipe.

	714 lin. ft. May, 1906.	1 009 lin. ft. July, 1906.
Laying track for steering alligator	$71.48	$43.98
Moving and erecting superstructure	209.94	358.44
Moving plates	202.50	252.44
Repairs to alligator	58.50	2.50
Bending rings	32.87	59.87
Placing reinforcement	126.94	138.13
Mixing and placing concrete	709.68	943.74
Watering	45.00	78.27
Pointing up and brush-coating inside	96.50	117.37
Blacksmith's work	30.00	25.00
Whim	23.87	28.75
Screening and hauling sand and gravel	183.13	300.00
Total	$1 880.41	$2 355.49
Barrels of cement used	466½	627
Number of days work	18	26
Labor cost per linear foot of pipe	$2.63	$2.33
Labor cost per cubic yard of concrete	5.93	5.25

A gang consisted of a foreman at $175 per month, a sub-foreman at $3.50 per day, and the following laborers at $2.50 per day: one bending the reinforcement rings; two placing the reinforcement; four taking down, moving and erecting the stationary plates; four placing the concrete and outside lagging; two wheeling concrete; six mixing concrete; one wheeling sand and gravel; one watering the finished pipe; four laying track for the steering apparatus, moving the superstructure and hangers, mixing boards, runways, etc.; one pointing and finishing inside the pipe; and one on the whim and doing miscellaneous work. The labor was principally Mexican, and only fairly efficient.

Results of Leakage Tests.

The leakage in the pipes was measured by observing the water level in them, all water being shut off. The head mentioned in the tables is the elevation of the water level above the lowest point in the pipe. The periods are consecutive in each case, that is, on January 25th the periods were during 2 consecutive hours, and on January 26th, during 6 consecutive hours, etc.

From February 26th to March 15th the pipe was in use a large part of the time. Various longitudinal cracks developed from time to time and were repaired. The next opportunity to measure leakage was from March 15th to 22d, after all the cracks had been repaired, since which time no more have appeared.

During the construction of the south line of the Pinto pipe, one lot of inferior cement, containing free lime, was received on the work, and a portion of it was used before being discovered. The result was a slower setting concrete, and at several places the upper stationary plates were removed too soon, allowing the concrete inside the reinforcement to settle and part from the outside.

Of these places, the worst one was repaired before the test of December 14th was made, but several minor ones, as well as most of the transverse joints, were not repaired until after that test.

TABLE 2.—Leakage Tests.—Pinto Pressure Pipe.—North Line.

This pipe was built between June and November, 1905, and first filled with water on January 25th, 1906.

Date.	Duration of test. Hours.	Minutes.	Leakage, in gallons.	Gallons per hour.	Average head.
Jan. 25, 1906	0	30	1 225	2 450	30.2 to 26.5
" 25, 1906	0	30	1 225	2 450	
" 25, 1906	0	30	1 130	2 260	
" 25, 1906	0	30	992	1 984	
Jan. 26, 1906	1	00	.....	2 205	30.5 to 22.4
" 26, 1906	1	00	.....	1 960	
" 26, 1906	1	00	.....	1 837	
" 26, 1906	1	00	.....	1 592	
" 26, 1906	1	00	.....	1 102	
" 26, 1906	1	00	.....	1 225	
(The pipe was full of water from January 26th to February 17th.)					
Feb. 17, 1906	1	00	.....	300	21.5
Feb. 22, 1906	1	00	.....	183	27.9
(On February 26th a longitudinal crack, 40 ft. long, developed.)					
Feb. 26, 1906	1	15	7 035	5 628	26.0 to 20.2
" 26, 1906	12	15	4 490	367	20.2 to 16.5
" 26, 1906	1	00	.....	86	16.5
(This test shows the effect of a crack, and the effect of a small reduction of head.)					
Mar. 15, 1906, 8:15 A. M. to Mar. 22, 1906, 6:30 A. M.	2	30	375	150	26.9
	7	00	350	50	26.6
	14	30	1 650	114	26.3
	4	15	475	112	25.9
	5	00	420	84	25.6
	16	45	1 575	94	24.7
	6	45	460	68	23.9
	19	00	1 740	92	23.0
	6	15	375	60	22.1
	13	30	1 610	119	21.3
	11	30	715	62	20.4
	11	15	1 100	98	19.6
	13	00	730	56	18.9
	13	30	730	54	18.3
	11	00	460	42	17.8
	10	30	375	36	17.4
Dec. 19, 1906	16	00	9 893	618	30.5 to 20.9
	1	00		550	
	1	00		458	
	1	00		458	
	1	00		458	
Jan. 30-31, 1907	24	00	92	3.8	30.5
(This test shows the effect of a run of muddy water.)					

TABLE 2.—(*Continued*).—LEAKAGE TESTS.—PINTO PRESSURE PIPE.—SOUTH LINE.

Built March to August, 1906, and first filled on December 15th, 1906.

Date.	Duration of test. Hours.	Minutes.	Leakage, in gallons.	Gallons per hour.	Average head.
Dec. 15, 1906.....	1	00	18 320	18 320	30.5 to 15.5
	1	00	3 664	3 664	15.5 to 12.5
	1	00	489	489	12.5 to 11.6
	1	00	366	366	
	1	00	290	290	
Jan. 26, 1907.....	2	00	3 191	1 595	30.5 to 27.9
	2	00	3 100	1 550	27.9 to 25.4
	12	00	13 648	1 137	25.4 to 14.2
	2	00	641	320	14.2 to 13.7
Jan. 29-30, 1907.....	1	00	2 198	2 198	30.5 to 28.7
	1	00	2 107	2 107	28.7 to 27.0
	1	00	1 832	1 832	27.0 to 25.5
	1	00	1 832	1 832	25.5 to 24.0
	1	00	1 649	1 649	24.0 to 22.7
	1	00	1 465	1 465	22.7 to 21.5
	18	00	9 984	555	21.5 to 13.3

TABLE 2.—(*Continued*).—LEAKAGE TESTS.—COTTONWOOD PRESSURE PIPE.—SOUTH LINE.

Built between December 25th, 1905, and January 26th, 1906, and first filled on March 9th, 1906.

Date.	Duration of test. Hours.	Minutes.	Leakage, in gallons.	Gallons per hour.	Average head.
Mar. 9, 1906.....	0	30	535	1 070	38.4 to 34.3
" 9, 1906.....	2	30	1 452	580	
" 9, 1906.....	1	00	.....	473	
" 9, 1906.....	1	00	.....	443	
" 9, 1906.....	1	00	.....	370	
Mar. 10, 1906.....	0	30	1 475	2 950	49.0
Mar. 27, 1906.....	2	30	38 100	15 200	74 to 18.
Sept. 22, 1906.....	7	00	0	0	74

The south line was the first one constructed at Cottonwood. Some time in April the pipe failed by blowing out a hole about 4 ft. square in its top. This was at the point where the first roof plates were removed, and would indicate that they were removed too soon, allowing the concrete inside the reinforcement to settle a little and part from the reinforcement and the outside concrete. The hole was cut out to solid work, and patched.

TABLE 2.—(*Continued*).—LEAKAGE TESTS.—COTTONWOOD PIPE.—NORTH LINE.

Built January 8th to 20th, and first filled on March 9th, 1906.

Date.	Duration of test. Hours.	Minutes.	Leakage, in gallons.	Gallons per hour.	Average head.
Mar. 9, 1906	0	40	167	251	24.0 to 22.5
	2	30	591	237	
	1	00	.....	177	
	1	00	.....	121	
	1	00	.....	98	
Mar. 10, 1906	0	30	3 540	7 080	69.0
	2	30	12 500	5 000	60.0
(8-ft. longitudinal crack opened.)					
Mar. 23, 1906	2	15	4 525	2 010	60
	0	30	1 048	2 097	73
Mar. 27, 1906	2	20	9 000	3 860	74.0 to 60.7
Mar. 28, 1906	5	45	.....	1 170	73 to 63
Mar. 29, 1906	18	45	.....	800	58
Apr. 16-17, 1906	26	00	.....	39	74
May 24-26, 1906	55	00	863	16	74
May 28-29, 1906	48	00	000	00	74
Sept. 22, 1906	24	00	000	00	74

Between March 10th and 27th various short longitudinal cracks developed and were repaired. The pipe was in service intermittently. Since the end of March the pipe has been almost constantly in service.

CONCLUSIONS.

The very slow setting cement used on this work rendered it impracticable to work continuously on account of the excessive number of stationary plates which would have been required.

With a cement setting in average time, the continuous process would certainly be practicable and advisable; and a machine similar to the one described herein, or designed to accomplish similar results, would probably be the best solution of the question of forms.

The necessity of continuous work may be said to vary with the temperature at which the pipe is constructed; at low temperatures it would be almost a matter of indifference; even at high temperatures it is probable that continuous work would not be absolutely necessary, because a method of making connections which would result in a nearly water-proof joint could probably be devised.

There are many engineering works, in process of construction, or projected, for conveying water under pressure, where similar reinforced concrete pipe could be used, and would be, were engineers satisfied as to its first cost, durability and reliability.

The question may be asked, what is the maximum head for which this kind of construction could be used? The precedent for such construction, as well as the literature on the subject, are both believed to be quite meager, though the writer has had little opportunity for searching engineering literature. Attention might be called to a paper* by J. H. Quinton, M. Am. Soc. C. E., entitled "Experiments on Steel Concrete Pipes on a Working Scale."

The excessive amounts of leakage reported in that paper would seem to have been due to the use of a dry mixture, and the writer would take decided exception to the conclusion (expressed on page 55), that "reliance for impermeability must be placed on the plastering rather than on the material of the pipe." Reliance should be placed upon a wet mixture of the material of the pipe.

There is no doubt that the first cost would be less than for either cast-iron or riveted-steel pipe, and would be little if any in excess of wood-stave pipe.

As regards durability, the question is as to the relative durability of the metal in the various kinds of pipe, disregarding for the moment the life of the wood staves.

The reinforced concrete pipe should be far less likely to be destroyed by electrolytic action than either cast-iron or steel pipe. The reinforcement receives a coating of cement which stays with it when the surrounding concrete is cracked or broken away, and the question becomes one of the relative efficacy of the cement coating on one hand, and the asphalt coating of the metal pipe on the other, remembering that the cement coating is absolutely protected against abrasion, and also enclosed in a manner which renders inspection difficult and incomplete.

It may be observed here that the metal in the reinforced concrete pipe possesses the same advantage over the metal in the riveted-steel pipe which has been advanced in favor of the bands on wood-stave pipe; *i. e.*, of form, being a rod with a diameter considerably greater than the thickness of the riveted-steel pipe. In

* Water Supply and Irrigation Paper No. 143 of the United States Geological Survey.

other words, given a certain quantity of steel per linear foot of pipe (enough to carry the load), the most durable form would be that with the least amount of exposed surface.

The problem of inspection might be solved by cutting into the steel occasionally at suspected points, such as at some crack or leak. The reinforcement in the concrete pipe should have a much longer life than the bands on the wood-stave pipe, though, on the other hand, the latter can be readily inspected and renewed.

Of course, as to the relative permanence of wood and concrete, there can be no question, even admitting the claims of the most ardent wood-stave advocates.

The reliability, or safety against sudden failure under a high pressure, seems to the writer to be simply a matter of correct design (to be determined, doubtless, by experiment), and the character of the inspection of the materials and construction. It is not necessary to state that the inspection should be absolutely first-class. It would seem that in correct design the relative quantities of concrete and steel should be such that the concrete in shrinking cannot compress the steel, but will crack; then, with nearly perfect adhesion of the two, there should be many cracks, but so minute that they will readily silt up.

Whether the concrete cracked at few places or many would depend upon the quality of the concrete, the relative quantities of concrete and steel, and the degree of perfection of the adhesion. In this there is a field for experiment, in order to determine the strength of adhesion of concrete and steel, the best form of reinforcing rod, and the amount of shrinkage during the setting of various mixtures of concrete.

It will undoubtedly be found that there is a minimum advisable spacing for the reinforcing rings, on account of their tendency to form a plane of cleavage and thus separate the concrete into an inner and an outer shell; also to insure the complete filling of the entire space with the concrete. For a large quantity of steel in the section, the arrangement might be in the form of two or more rows of rings staggered.

This paper is presented, not as pretending to solve the problem, but with the hope that the governing considerations have been stated correctly, and that the suggestions will be of some value.

In conclusion, the writer wishes to acknowledge valuable assistance derived, during the construction of the pipe and the repair of the cracks, from a free discussion of the various problems with Louis C. Hill, M. Am. Soc. C. E., Supervising Engineer; F. Teichman, M. Am. Soc. C. E., Designing Engineer, and Mr. A. L. Harris, Assistant Engineer; also the exceptionally conscientious work of Mr. A. P. Cox, Foreman.

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PAPERS AND DISCUSSIONS.

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THE BRACING OF TRENCHES AND TUNNELS, WITH PRACTICAL FORMULAS FOR EARTH PRESSURES.

By J. C. Meem, M. Am. Soc. C. E.

To be Presented October 16th, 1907.

In this paper the sheathing and bracing of trenches and tunnels in dry and water-bearing materials, will be treated under the general subject of bracing. In order that there may be no misunderstanding, the term "sheeting" will be used for that class of sheathing which is set in or driven coincidentally with the excavation. That class of sheathing which is driven ahead of the excavation, or beyond its final limits, will be referred to as "sheet-piling."

Ordinarily, sheeting is set in or driven by hand-mauls, whereas sheet-piling is driven by pile-drivers. In order to make the descriptions as clear as possible, reference is made to Figs. 1 to 4, which show in a general way the different types of sheeting and bracing.

Fig. 1 shows a general type of open trench sheeted with two sets of, or "double," sheeting.

Fig. 2 shows a detail of the principal features of the sheeting

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

(ordinarily 2 or 3-in. spruce or Virginia pine), the ranger with the engaging brace, and the cleats and lugs for holding them in position.

Fig. 3 shows a general type of excavation in a coffer-dam, sheeted with 12 by 12-in. tongued and grooved sheet-piling, driven between guide-wales, and penetrating beyond the limits of the excavation, but not sufficiently far to do away with the necessity for bracing. These guide-wales are usually bolted to ordinary piles driven ahead of the sheet-piling and removed as it approaches them.

Fig 4 shows the cross-section of a general type of hand-driven tunnel or drift. The cap, legs, and sill are clearly defined, with a spreader under the cap, the rear ends of the front lagging resting on the cap, and the front ends of the rear lagging superimposed above everything, with the waling pieces and fillers and wedges between. The same terms hold good for the sides. The fillers shown at the right of the sketch just over the cap are put in temporarily to hold the waling piece in position until the lagging or poling boards can be driven.

Referring now to the general question of earth pressure, in connection with its action on sheeting and bracing, the writer believes that this subject has never been developed so as to reconcile the theoretical with the practical conditions. It will be his endeavor to develop a practical basis in connection with which it will be possible at all times to effect an approximate reconciliation between the actual conditions of stability of earth and the theoretical formulas or resultants arising therefrom.

In all his experience, the writer has used the diagram, Fig. 5, for calculations of earth pressure, whether applied to retaining walls or to sheeting and bracing.

If $B\ C$ be the line of the sheeting, and $D\ C$ the natural slope of the earth, b being the angle of repose, then the mass of earth causing pressure against the line, $B\ C$, is contained within the triangle, $D\ B\ C$.

The weight of the earth in this triangle rests on $D\ C$, and its thrust is transmitted to $B\ C$, not through the toe of each layer at the foot of its slope line, but by the arching effect of this earth between the lines, $B\ C$ and $D\ C$.

For purposes of calculation, it is probably not far from correct to assume that a line, $A\ C$, bisecting this triangle, $D\ C\ B$, measures with $B\ C$ an area equivalent to the weight transmitted as thrust

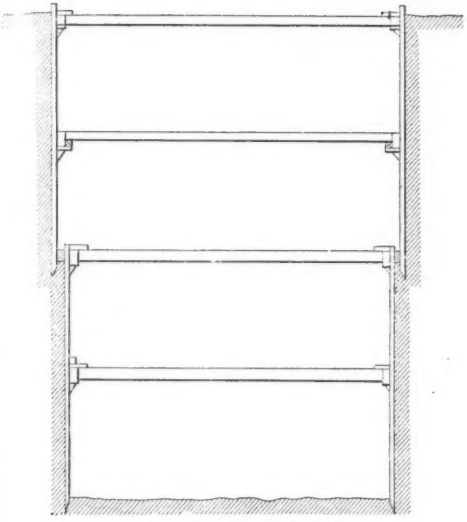


FIG. 1.

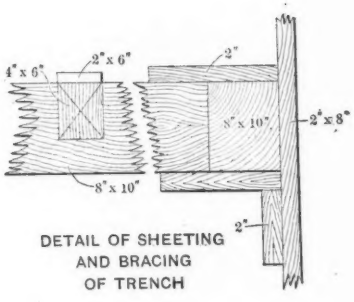


FIG. 2.

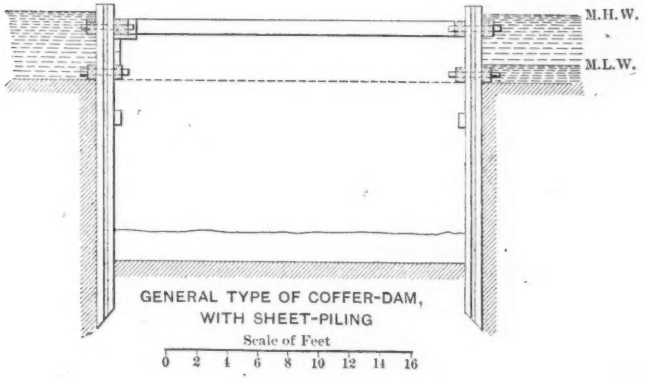


FIG. 3.

against this line, *B C*. Also, it is true that the center of pressure against *B C* is where a perpendicular from the center of gravity of the triangle, *A C B*, meets this line.

The writer is fully aware that in making this assumption he is

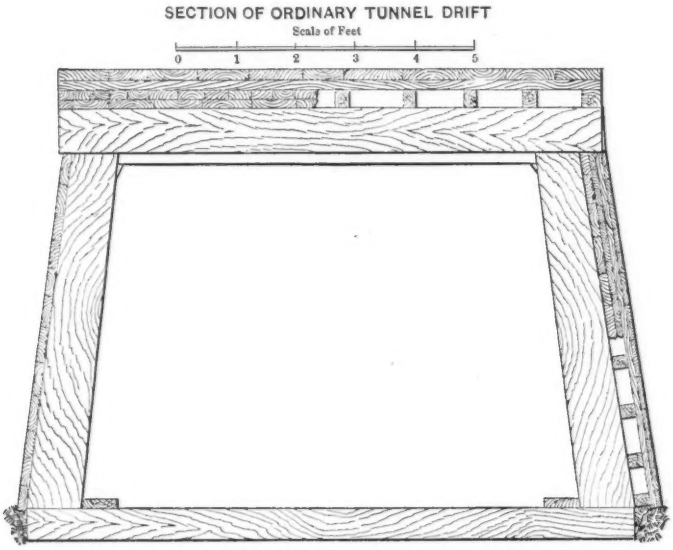


FIG. 4.

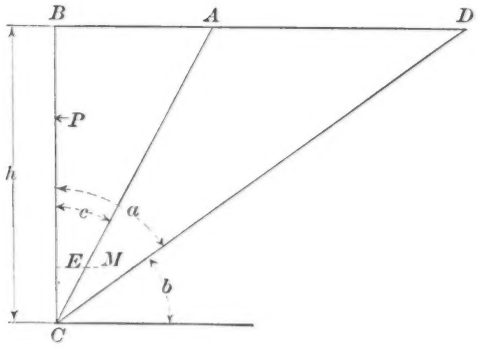


FIG. 5.

going contrary to the general theory, which assumes that earth pressure acts along the line of rupture and parallel with that line, and is therefore greatest at the toe, but he wishes to state that this theory is not borne out in actual practice, and that all closely-sheeted,

well-braced trenches invariably show a heavier pressure at the top than at the bottom. Any attempt to assume a theoretical condition which is contrary to this fact must be of little value to engineers in making practical calculations. The writer is aware that many retaining walls have been built from designs based on this theory; and he may state parenthetically that it makes little difference, practically, which form of reasoning is applied to retaining walls. It does, however, make a vast difference which form of reasoning is applied to a braced trench, or to a concrete wall reinforced horizontally; and, while the writer does not wish to contradict this theory, if based entirely on a theoretical condition of frictionless material, he does wish to advise against its use in ordinary practice. In other words, if it be assumed that *D C* is a solid plane, and that the triangle, *D C B*, is filled entirely with particles which are absolutely without friction, and therefore the weight of one upon the other transmits accumulatively the weight of all entirely and directly to the bottom, then the truth of the theory noted above cannot be controverted. The writer is convinced, however, that such a condition does not exist, and that earth pressures and aqueous pressures are not similar; for, in dealing with ordinary materials, it is impossible to proceed with any practical calculations without taking into account the frictional resistance of these materials and their arching effects, which render it virtually impossible to consider their action as in any way allied to hydrostatic action. For instance, the writer has repeatedly observed (where trenches have been sheeted from *B* to *E*, Fig. 5, and the excavation has been continued below *E* without sheeting), undercutting excavations which have been made (in loams, clays, or moist sands) back along the line, *E M*, by the use of light poling-boards driven in under the toe of the sheeting at *E*, without disturbing the stability of the mass above. He is satisfied that if this sheeting had been so poorly put in as to cause the stability of the mass to be disturbed, it would have manifested itself by the continual dropping of masses of material from above, rather than as a constant pressure, as would have been the case had the material been full of water or absolutely frictionless. And, if any small holes should be left between these poling-boards in absolutely dry sand, it would "bleed" in through these orifices just as the sand

runs into an hour-glass, until the hole had gone to the top of the excavation, but at no time would there be observed any continuous pressure which could be defined in any way as equal to the entire weight of the sand from the bottom to the top over the unsheeted area. It may be, and the writer has frequently observed also, that the lower part of a trench may be left unsheeted, as from E to C, and for a considerable distance longitudinally in clays and moist sands, without disturbing the stability of the face, $E\ C$, and yet more or less heavy pressure may be observed in the bracing above. This can only be explained on the theory of the arching effect of the material above, one buttress of the arch being $B\ E$, and the other $D\ C$. If this be correct, there can be no doubt of the action being wedge-like, with the center of pressure opposite the center of gravity. Any engineer who has had to do with excavations must be aware of the fact that pressures are frequently developed in the top braces and rangers while men are excavating with impunity beyond the limits of the sheeting at the bottom of the trench. It is possible, also, at any time to cut or remove the bottom sheeting (except in dry sand) for a considerable percentage of the vertical distance from the bottom, and for indefinite lengths, without interfering with the stability of the bank above, provided the sheeting is removed without jarring. Any practical man, however, will admit that it would be suicidal to remove any one of the braces near the top of the excavation, particularly after the ground had stood for any considerable time.

The practical application of the foregoing will now be shown, and the formula be demonstrated.

If b (in Fig. 5) = the angle of repose,

$a = 90° - b$, and

$c = \frac{a}{2}$,

h = height = $B\ C$,

w = weight of 1 cu. ft. of earth.

Then, the area of $A\ C\ B = h \times \frac{h \tan. c}{2}$, and the weight of the mass of earth causing pressure on $B\ C = \frac{w\ h^2 \tan. c}{2}$.

The resultant pressure of this mass would occur at two-thirds of the height, or at P, in Fig. 5.

In the case of a well-sheeted and braced bank, there would be no overturning moment, but there would be a thrust, represented by the general tendency of the triangle, *A B C*, to slide along the line, *A C*, and therefore move out and exert pressure in a horizontal direction.

To understand this more clearly, it might be well to assume (in Fig. 6) that the lines, *D C A* and *D C B*, are blocks of ice which are held in place along the line, *B C*, by their weight impinging on this line, and on the line, *A C*, by a rigid strut bearing against that line at *P*. If the pressure at *P* be slightly released, the whole triangle, *A B C*, will assume a new position, A_1 B_1 C_2. If, again, *A D C* be taken as a solid wedge bearing against a solid block, *D C*, and the wedge be forced down, then, in

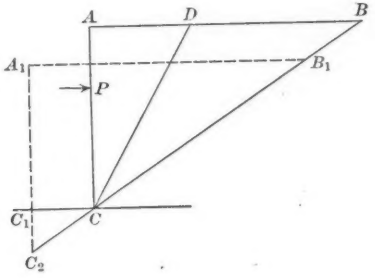


FIG. 6.

order that it may be resisted most effectually at any one point, this resistance should be placed at *P*. Or, in a word, the writer believes that the action of earth pressure in properly braced trenches is more closely allied to that of a coherent solid than to that of an aqueous or frictionless mass.

If, now, these pressures be applied to an ordinary sheeted and braced trench of an assumed depth of 40 ft., and if the weight of earth be assumed at 90 lb. per cu. ft., the pressures obtained at the braces shown in Fig. 7 will correspond with the figures in the rectangles opposite these braces. The maximum pressure on any portion of a trench sheeted in this manner would occur at the second brace, where the pressure for the assumed case would eventually be 8 640 lb. per ft. If these braces are spaced 10 ft. apart, it would be necessary to use a 12 by 12-in. yellow pine ranger to resist this

pressure (with a factor of safety of 3), and the third, fourth and other rangers would be of correspondingly smaller cross-sectional area. It is rarely found in practice, however, that it is necessary to use a ranger as heavy as that required by the theoretical conditions here assumed, for, if the trench be well-sheeted and braced, the horizontal arching effect of the material will come into play,

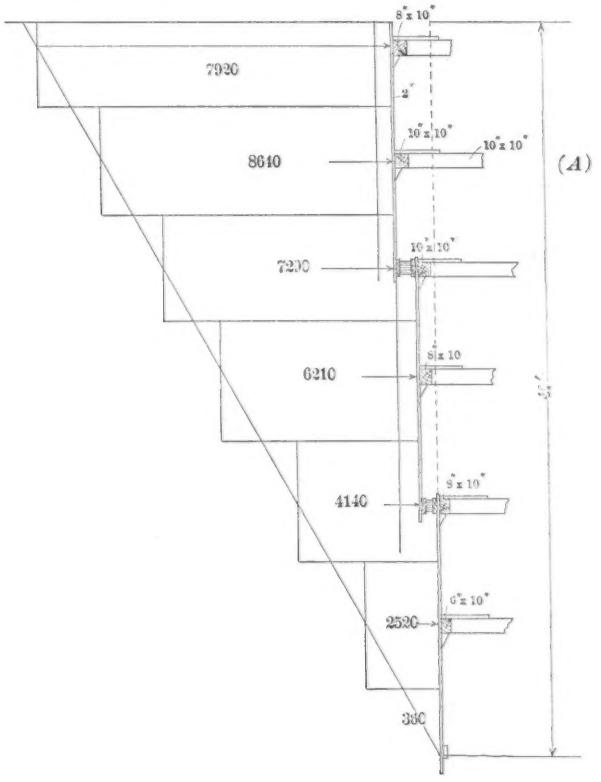


FIG. 7.

and will transmit itself from brace to brace and allow the use of a lighter ranger. It is also customary, within the limits of good practice, to use much lighter sheeting than that which would be theoretically required to maintain or resist this pressure, as the braces and rangers, if properly placed, take up the pressures and allow the arching effect previously noted to perform its work.

In Fig. 7 are noted the sizes and kinds of sheeting and bracing which would be used in ordinary practice in a trench 40 ft. in depth, and, while not recommended as theoretically strong enough, they give satisfactory results in ordinary ground where the trench does not have to stand too long, and always assuming that the bracing is properly put in originally. The top brace here shown is 8 by 10-in., the second and third are 10 by 10-in., the fourth and fifth are 8 by 10-in., and the bottom one may be a 6 by 10-in. These sizes apply to a good grade of Virginia or short-leaf yellow pine. Ordinarily, the toe of the sheeting is driven 1 ft. or more into the bottom material, which holds it in place without the necessity for bracing this toe. The braces sustaining the rangers (except in very narrow excavations) should be fully as large as the rangers themselves, as any tendency to distortion might be fatal to the stability of the banks; and, if the trench is very wide, longitudinal spreaders should be placed between the braces at sufficiently frequent intervals to prevent the possibility of distortion. These spreaders obviate the necessity of using heavier braces.

The writer believes that there is a limit of depth beyond which it is not possible to brace a trench against the pressures which would be developed, and he believes that this limit could be defined by a simple practical calculation, depending, of course, upon the nature of the soil through which the trench was dug. For example, if a trench be sunk 20 ft. and stopped, the pressure developed at the 15-ft. level will not be excessive, whereas if it be continued to 60 ft. the bracing will have to be heavily reinforced at the same 15-ft. level; and, if the trench be carried down to an indefinite depth, no bracing would eventually be able to withstand the pressures at this same point, owing to what may here be described in a homely way as the "topheaviness" of the bank. Anyone who has had to do with deep trenches or tunnels, however, must realize that an exposed face of earth is under no more pressure at the bottom of the deepest trench or tunnel than it is at the bottom of a shallow one.

Reference is here made to Fig. 1, Plate LXX, which shows the bottom of a lined tunnel (at a depth of some 70 ft.) which had been driven with an ordinary shield, and from the bottom of which several cast-iron plates had been removed. The places from which

the plates were removed show an exposed face of moist sand, and it is clearly evident that it is in as quiescent and undisturbed a state as though the exposure had been made only a few feet from the surface. The rod shown in the photograph is vertical.

The danger in sheeting a trench arises mainly from three causes:

a.—In driving the sheeting carelessly and allowing slips to occur behind it; or, in the case of clayey soils, not properly guarding against voids which may occur behind the sheeting. The natural tendency of earth eventually to fill these voids causes slips, which develop not only the full pressures theoretically provided for, but frequently, by reason of the shock incidental to the velocity of slip, cause increased pressures to impinge against the sheeting and incidental bracing.

b.—In not fully tightening the braces by the use of wedges driven practically to refusal; and

c.—Because strata of quicksand may be uncovered in ordinary soil, thereby developing hydrostatic and unbalanced pressures on the sheeting and causing stresses not properly provided for.

The next consideration is that of bracing and sheeting and its relation to earth pressures in subaqueous or other soils so saturated as to be under hydrostatic pressure.

There appears to be no controversy as to the generally accepted theory and formula in connection herewith, and they will merely be discussed in order to preserve the continuity of this paper.

Fig. 8 shows graphically the theory of hydrostatic pressure, which assumes that it is cumulative vertically and constant in the horizontal planes, and that the center of pressure is always at a point one-third above the base. If, now, it be assumed that $A\ B$ is sheet-piling which has been driven through water and into the ground at C, penetrating sufficiently far beyond O to cause it to act as a cantilever, then the moment tending to overturn this sheet-piling is as follows:

If $h =$ the height (in Fig. 8),

$w =$ the weight of 1 cu. ft. of water,

and, if the width of each pile be 1 ft., then

$$h \times \frac{h}{2} \times w = \frac{w\,h^2}{2} = \text{the weight bearing against each pile,}$$

and

$$\frac{w\,h^3}{6} = \text{the moment tending to overturn each pile.}$$



FIG. 1.—SAND IN REPOSE AT SIDE AND BOTTOM OF TUNNEL.

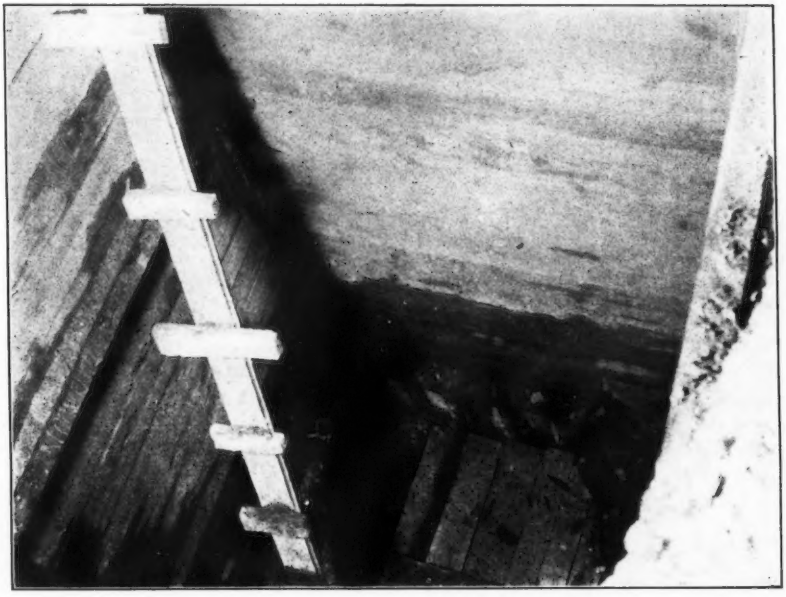


FIG. 2.—PIT, 6 FT. SQUARE, LINED WITH HORIZONTAL SHEETING.

If a brace be placed at the point, H_1, the piling becomes a beam with the load distributed over the whole area, the resultant being at P. The writer is not convinced that it is necessary to consider the full hydrostatic pressure on that portion of the pile represented in Fig. 8 by C O. He believes that the frictional resistance of the earth here prevents this full hydrostatic pressure from being developed, but he would not be willing to neglect this in making practical calculations, and therefore he believes it should always be taken at its full value. The same reasoning applies to subaqueous tunnels, or to any subaqueous structure in soil sufficiently permeable to admit water in reasonably large quantities.

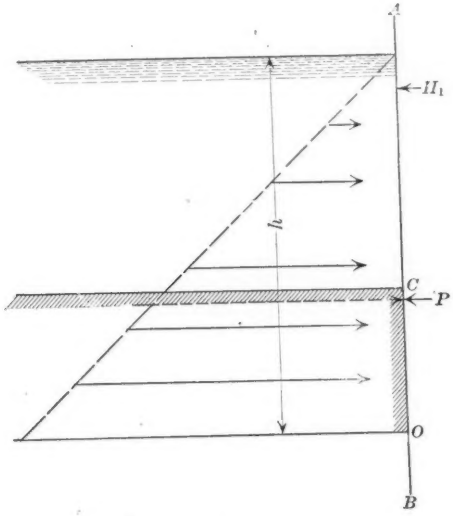


FIG. 8.

The next question to be taken up will be earth pressures on tunnels or subterranean structures, where it is necessary to consider the other side of the pressure areas noted in the development of the formulas for pressures in open trenches.

Referring to Fig. 9, if it be assumed that B D J I is a tunnel (the area of which will be taken as a square, in order to simplify the assumptions), and that H D or D F is the natural slope of the earth above this tunnel, then:

a = the angle of repose,

b = the complement of the angle of repose, and

$c = \frac{b}{2}$.

As a first assumption, it is unquestioned, of course, that all earth contained in the triangle, *B C D*, necessarily presses directly on the roof of the tunnel. And if the assumptions made at the beginning of this paper are true for open trenches, then it is also true that all the earth contained in the triangle, *A C D*, bears directly upon the line, *C D*, and therefore all this weight likewise is transmitted to the tunnel and all the pressure of the earth in the triangle, *A D L*, goes to the line, *L D*, arching itself somewhere below the triangle, *B A D*, in a curve approximating the line, *B S D*, so that, in a well-braced tunnel, the only pressure on

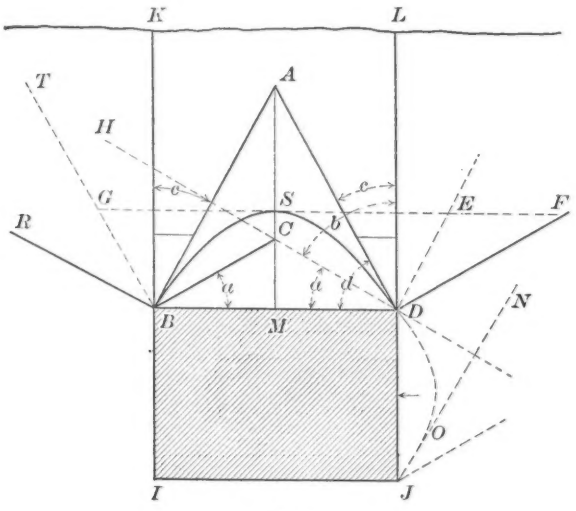


FIG. 9.

the roof would be that due to the weight of the material below this line. In order to be consistent and carry out the line of reasoning in the original assumption, however, provision must be made for the pressures of all the material in the triangle, *B A D*. No pressure beyond the lines, *B A* and *A D*, can be transmitted to the tunnel unless the ground contains water in such quantities as to make the pressure hydrostatic. Of course, if the tunnel is a subaqueous one, the pressure on the line, *B D*, for purposes of practical calculation, must be that due to the hydrostatic head of the water measured by its depth to the line, *B D*, and by the width of the tunnel opening.

Returning again to earth pressures free from excess of water, it is found, of course, that the larger the angle, *a*, the greater is the resultant pressure upon the tunnel. It is possible that some may argue from this that the greatest pressure will occur in clayey soil where the earth stands vertically. This supposition, however, is erroneous, because, any soil which will stand vertically and continue to stand vertically under any circumstances must be considered in the same way as solid rock, and cannot be properly classed as material for which bracing is necessary. As a matter of fact, however, clays are treacherous soils for tunneling, and frequently develop pressures by squeezing or sliding horizontally, for which it is difficult to provide.

If, now, it be assumed that the square, *B K L D*, is made up entirely of blocks of ice (or frictionless solids) having an angle of repose of 90°, the full weight of this material would have to be provided for in bracing across the tunnel roof, *B D*. If, on the other hand, a material, such as dry sand, be considered, in which the angle of repose is very flat, the arching effect of this material comes more greatly into play by reason of its tendency to slide along the angle of repose, and therefore, the condition of least pressure that can come upon a tunnel in dry ground is where the angle of repose of the superimposed material is least, always providing the material is held by close sheeting. In a word, then, the greater the angle of repose the greater the pressure to be provided for, and this leads to the conclusion that dry sand of a small angle of repose would prove the best material for tunneling if it were possible to sheet and brace the roof absolutely without disturbing its equilibrium. In practice, however, it is, of course, impracticable to drive a tunnel through sand of any kind without having some movement of material, and the dryer the sand, the more likely it is to run through any opening in the sheeting.

Erroneous ideas of tunnel pressures may be had from the fact that any bracing which admits the slightest settlement develops in consequence greater or less pressure, according to the degree of settlement, and the consequent movement, which is permitted to take place, but the writer is convinced, from long observation, that in reasonably careful work no pressures need be allowed for beyond the limits herein stated.

Here, again, it may be of interest to note that if a frictionless material could be imagined, resting in a trough made by the prolongation of the lines, *R B* and *D F*, measuring the angles of repose, allowance would undoubtedly have to be made for the full pressure of the weight of all the material contained within the prolongation of the lines of rupture, *B T* and *D E*. Assuming a case where a tunnel is so close to the surface that the arching effect is lost, for instance, if in Fig. 9 the surface of the ground be taken at *G E F*, it is probable that there would be obtained not only the full pressure of the ground directly above the opening, but an increase due to the lines of rupture, *B T* and *D E*. Therefore, in the writer's judgment, it is always wise to discontinue tunnel operations when the surface of the ground intersects, or nearly intersects, the perpendicular line, *A M;* and it is within the reasonable limits of good practice to tunnel when the surface of the ground is fairly well above the point, *A*. It may also be of practical interest to note that any longitudinal trenching should always be avoided if possible over the line of a tunnel while it is being excavated owing to the consequent destruction of the key to the arching effect of the ground.

As to the actual pressure:

Let l = the width of the tunnel;

$A\ M = h = \frac{l}{2} \times \text{tan. } d.$

Then the area, $B\ A\ D = \frac{l\,h}{2}$;

and, assuming that $a = 34°$, then $c = 28°$ and $d = 62°$;
and the tangent of d = approximately 2;
and l, of course = h.

The area, *B A D*, therefore, becomes $\frac{l^2}{2}$,

and $\frac{w\,l^2}{2}$ = the total weight per linear foot of tunnel,

where w = the weight of earth per cubic foot.

As to side pressures, the pressure against the sheeting, *D J* (Fig. 9), continues along a line of rupture, *J N*, stopping at some indefinite point, which, for practical purposes, may be taken at *O*, and making the only actual pressure in closely-sheeted work approximately within a line measured by the curve, *D O J*. An

excess allowance covering conditions of sheeting, ground, etc., in which judgment is a large factor, should be used in all calculations relating to the question of side bracing, to give a proper factor of safety in connection with this somewhat indeterminate quantity.

As to the question of shaft bracing, Fig. 10 is a cross-section of a square shaft of an area sufficiently small to give the surrounding earth a tendency to arch itself horizontally, it being very probable that such a shaft of reasonably small dimensions and driven as here shown will develop pressures somewhat as indicated by the circumscribed circle. It appears to be reasonably fair to assume that a circular shaft of not too large diameter, driven in dry ground or moist sand, will arch itself so that very little pressure is exerted

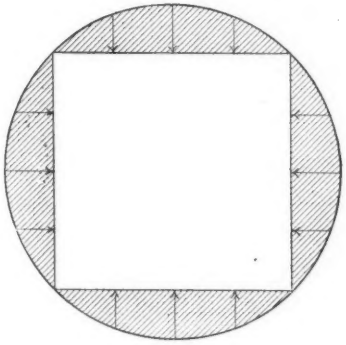


FIG. 10.

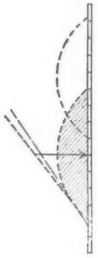


FIG. 11.

on the bracing in excess of that originally developed in making the sheeting and bracing tight. This excess pressure is small and indeterminate in actual practice, and may be measured by the intersection of the lines of the arching effect in a horizontal plane and the lines of rupture in a vertical plane, and somewhat as shown in the vertical section in Fig. 11. This pressure varies, of course, in direct proportion to the care with which the sheeting was originally placed. In view of this, it is true, both practically and theoretically, that a small shaft may be driven to any depth without developing any greater pressures below than are found near the surface. As soon, however, as the shaft becomes so large that the horizontal arching effect is destroyed, the action of the pressures becomes the same as the bracing in an open trench, and therefore

it would be impracticable to sink to any great depth a shaft the dimensions of which were such as to put it in the same category as trenches.

Attention is called to the photograph, Fig. 2, Plate LXX, which shows an underpinning pit sunk to a depth of about 18 ft. by the use of horizontal or well-diggers' sheeting. The bottom of this pit is at the level where ground-water has been struck, and is there sheeted with interlocking steel sheet-piling driven some 5 ft. into the ground to bring its toe well below the sub-grade of the adjoining excavation for which the underpinning is required. This pit can now be pumped out and excavated without danger of bringing in sand, and can then be filled with concrete to form a proper foundation for supporting underpinning timbers. The writer has personally supervised the work of sinking numbers of similar pits for different purposes, some to depths of 45 ft., without other bracing than the horizontal sheeting noted above, each set alternately bracing the other. It is also known that pits of this character, and not more than 5 ft. square, have been sunk by well-diggers to a much greater depth than those noted without using any bracing other than the sheeting of the character described above.

The writer believes that the practice of lining circular manholes with masonry walls the thickness of which increases with the depth is not consistent with good designing, and that a circular shaft may be safely designed with a masonry wall which has the same thickness at an indefinite depth as it has near the surface.

The remainder of this paper illustrates and discusses a few general types and methods of sheeting and bracing.

The ordinary sheeting, of course, is hand-driven vertically, as previously illustrated, but it is not always possible to drive sheeting, particularly in subway work, where much of the excavation has to be done under cover. In such cases, however, it is always possible to use cross, box, or horizontal sheeting, types of which have been illustrated in connection with the sinking of pits. This type of sheeting, of course, is more expensive to put in, but in some instances gives better results than its hand-driven prototype, as the work can be done more carefully and can be more closely watched to avoid the occurrence of voids behind it. It may be of passing interest to note that the writer on one occasion found a

void larger in size than the hand of an ordinary man behind sheeting which had stood for fifteen years in a clayey soil.* He does not desire to offer this as a reason, however, or even a good excuse, for leaving such voids.

The general type of bracing shown in Fig. 12 may be taken to illustrate the more usual methods in connection with openings as

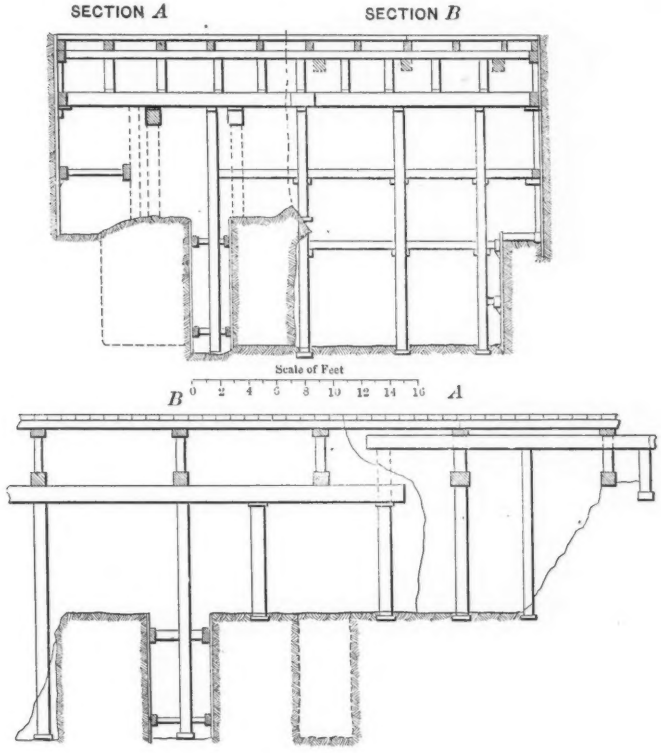


FIG. 12.

large as those required for the ordinary two-track subway. The general scheme in this is to dig the excavation in two or more levels, according to the depth, completing the excavation for a portion of one level before the other is begun. The decking is put in and

* Since preparing this paper the writer's attention has been called to a void recently found in excavating over a tunnel driven fifteen years before in sand. This void was large enough to admit one-half the body of a man.

carried on longitudinal sills, which, in turn, are braced from a lateral cap or caps, as shown, and where interference of pipes does not prevent. From this point the main cap is carried on temporary longitudinal I-beams or timbers of sufficiently large section and length to span from the solid ground ahead to the posting behind and carry one or more caps, according to the size and weight overhead. In carrying the excavation to its final level, after the first portion has been excavated, long posts, reaching from the main cap to the bottom, are put in in pits, as shown; or, if the longitudinal bars supporting the caps are sufficiently heavy and the superimposed weight is not too great, they may be put in in open excava-

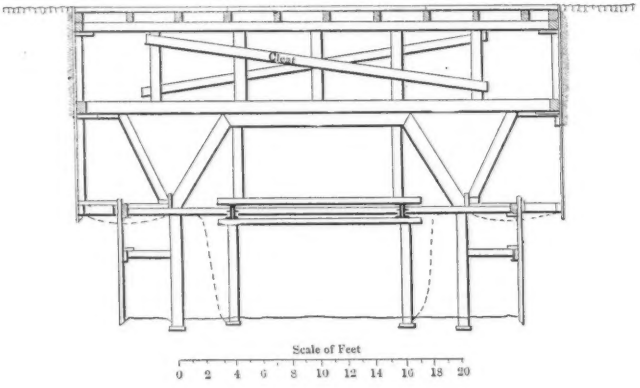


FIG. 13.

tion, as shown at the upper right portion of Fig. 12. The advantage of operating by this method is that the long posts, when once in place, give a vertical stability to the structure; but at the same time they are more or less cumbersome to handle, and not infrequently have to be cut up to be removed. Of course, the presence of pipes or other sub-surface or surface structures must change the form of bracing very materially, and the nature of the ground may also make considerable change in the method of operation.

In Fig. 13 is shown a type of bracing which has been used by Cranford and McNamee, in Brooklyn, in connection with their subway work. In this the decking where required is carried on longitudinal stringers, and where there are trolley tracks they are

carried on longitudinal I-beams. As close as possible to the top of the trench, and below the general line of the pipes, needle-braces are run from ranger to ranger, and below this a cap is set. This needle and cap are carried on temporary posts and rakers until the heavy side rakers or inclined legs shown in Fig. 13 can be put in. The built-up, continuous, channel-beams, shown in cross-section beneath the main cap, are then run ahead, and the posting is carried up from that. The excavation is then carried down along the dotted line (and sheeted, if necessary), and the main posts are put in under the channel beams, the load being carried on the diagonals while this is being done. The excavation is then widened to its full limit.

The "bench" shown on each side of the excavation serves the double purpose of allowing for the construction of the side sewers and forming a break in the pressure area measuring the thrust of the bank. It is believed that, even where sewers are not required, it is a wise precaution to maintain some form of bench at or near this point.

The advantages of this type of bracing are that it does away with the necessity of using long, heavy posts and temporary, long, heavy beams, as the longitudinal channel-beams make a tie which gives absolute stability to the shorter posting.

The interesting feature of Fig. 13, in connection with this paper, is that the heavy main brace, called the needle-brace, which runs from ranger to ranger, was calculated to do the heaviest work of the bracing, and was put by the contractors as nearly as possible at what they conceived to be the center of the heaviest pressure. The writer is thoroughly familiar with the work which this main brace has been called upon to do (in one instance it spans a continuous excavation for a six-track subway, and braces and carries the bracing for a double-track surface line and a double-track elevated railroad), and he can say positively, from his own knowledge, that at no time have the contractors ever seen fit to modify their first design of putting this main brace near the top rather than near the bottom of the trench.

Fig. 1, Plate LXXI, is a view of a section of this type of bracing for a four-track subway in Fulton Street, Brooklyn, and Fig. 2, Plate LXXI, shows the surface lines and bracing carrying the

columns of the elevated railroad, the supports of which are in turn braced directly by the timbering shown in Fig. 1, Plate LXXI.

In tunnel bracing, the writer is more familiar with two general types of timber-braced tunnels. One of these is the crown-bar

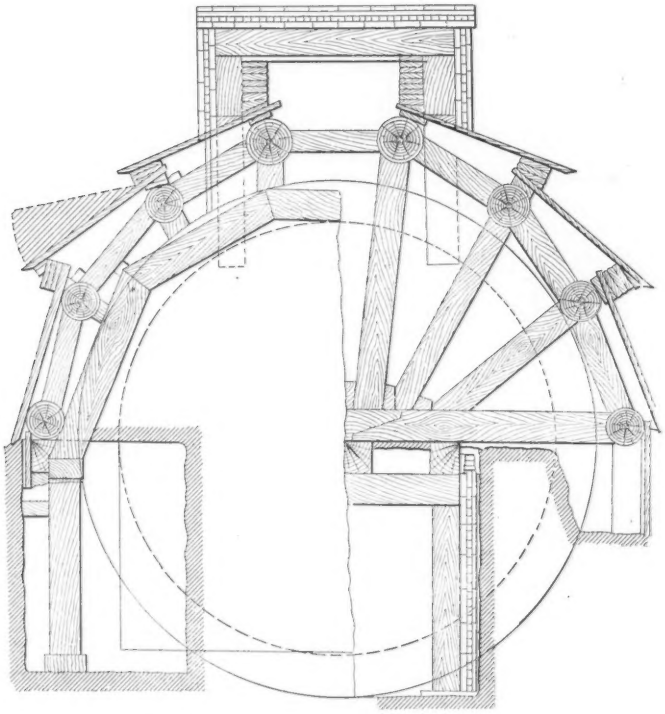


FIG. 14.

system, shown in Fig. 14. It is not necessary to do more than call attention to the general features of this type. In the ordinary crown-bar system it is customary to drive the bottom drift ahead of all other work and follow this closely with a top drift, as shown

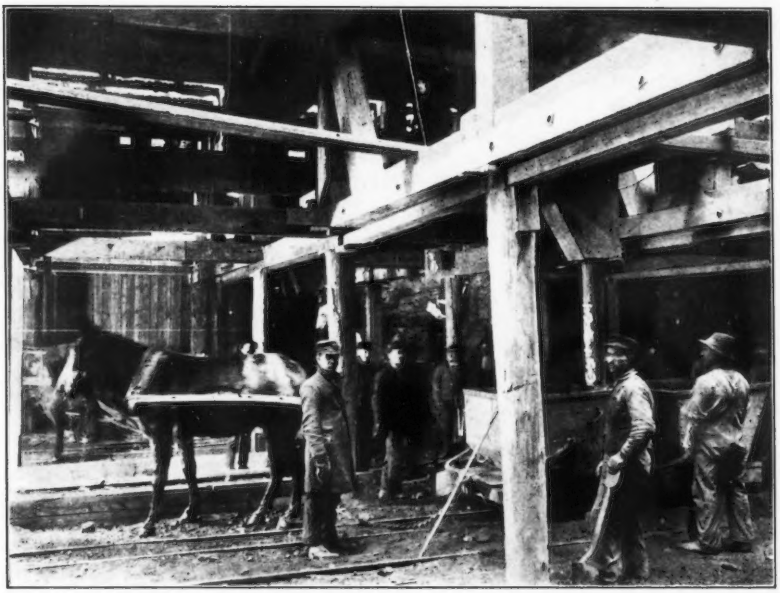


FIG. 1.—TYPE OF BRACING IN FULTON ST. SUBWAY, BROOKLYN.



FIG. 2.—A-FRAMES, SUPPORTING ELEVATED RAILWAY, OVER SUBWAY EXCAVATION, BROOKLYN.

in Fig. 14. The bars are placed in position in this top drift, the poling-boards are driven off approximately as shown, and the bracing is erected as the excavation proceeds. Where this type of bracing is used in rock tunnels it is, of course, unnecessary to drive a bottom drift, and the arch timber bracing shown on the left is usually put in underneath the bars as soon as the depth of excavation corresponding to the springing line of the structure has been reached. It is thus seen from Fig. 14 that, for the bar system alone, a circular tunnel of the size shown by the outer ring could be constructed, whereas with the arch timber bracing remaining in place, a tunnel no larger than that shown by the inner ring could be built.

The disadvantages of both these types of bracing are that so much space is required beyond the limits of the structure, and that it is impracticable to fill the voids over the masonry, even where dry packing of rock or brick is used; and it is virtually impossible to backfill them properly with sand or earth. Another disadvantage is the very prolific cause of settlement on account of the fact that the poling-boards do not finally rest in the plane at which they were started. This gradual lowering of the ends of these boards necessarily causes loosening of the material above and consequent settlement, with increased loading on the bracing, and while these items may not be of material importance in open country, they should be given the gravest consideration where this system is used under city streets.

Where arch timbers have been used, as in a few cases, in connection with the crown-bar system, and put in sufficiently high to clear the outer ring of the tunnel, it has been sometimes customary to run two bottom drifts ahead (as shown at the left of Fig. 14), setting in supports for the wall-plates before the upper excavation has been made. There are some instances on record in which the wall-plate has been directly underpinned after being put in place with a load on it. The writer has supervised the work of building tunnels of large diameter, and in one of the headings the arch timbers were used in connection with the crown bars and afterward removed; but in the remainder of the work with which he is familiar the arch timbers were used in connection with a special type of timbering shown in Fig. 15, all of which was eventually removed, leaving the tunnel sheeting bearing directly on the brick-

work. In this type the arch timbers were underpinned from the masonry which was put in in a centrally sheeted and braced trench, as shown, the entire masonry of the structure being built in three successive stages, of which the first is that noted in the bottom of the trench. In this method the outward thrust of the bottom legs of the arch, or segmental timbers, precludes almost entirely the possibility of any settlement while the sheeting for the middle trench is being driven. In dry ground there is practically no danger of any settlement to be caused from this method of under-

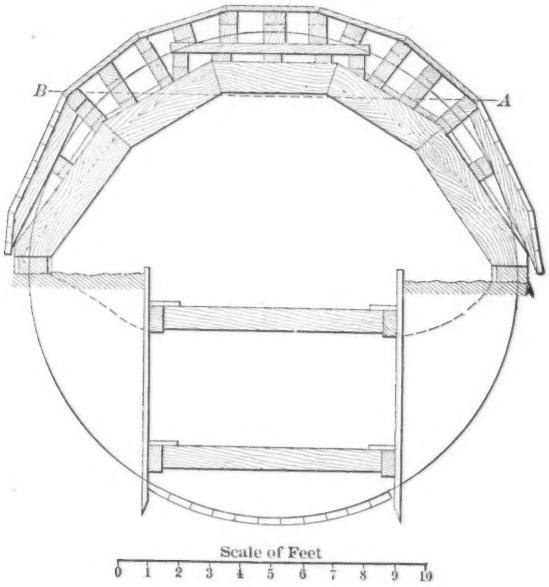
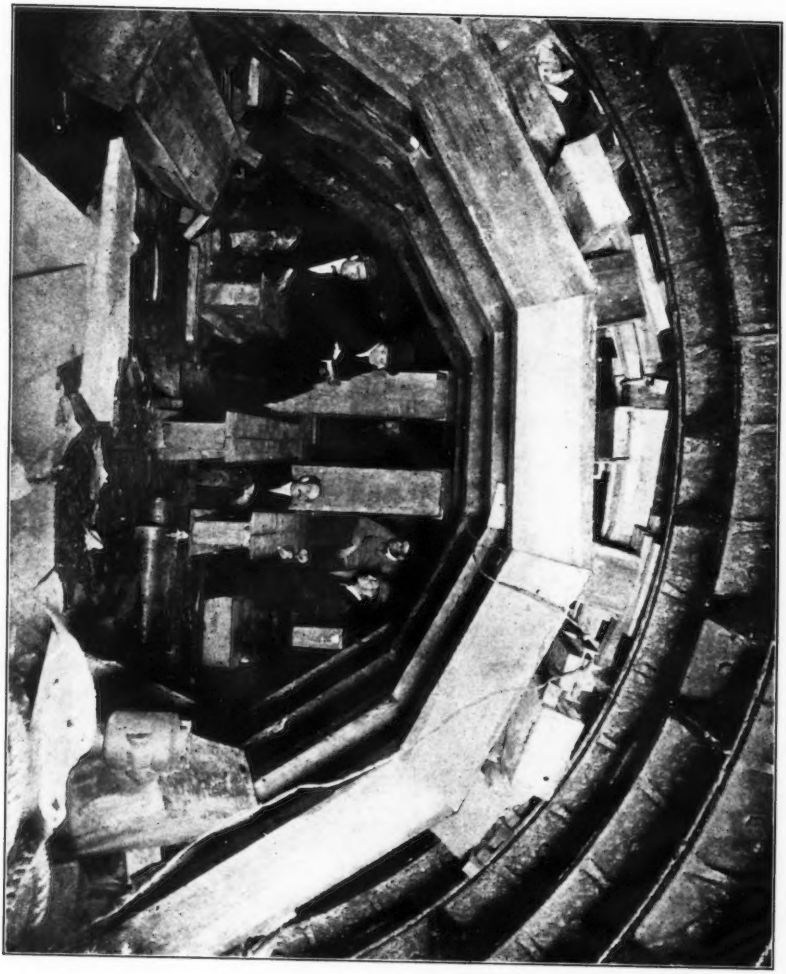


FIG. 15.

pinning, and the writer has supervised tunnels built safely by this method, where the ground-water level was normally 5 ft. above the sub-grade and had to be kept down by constant and heavy pumping through sand.

It may be of interest to state, in connection with the action of earth pressures, that it is almost always practicable to set in horizontal sheeting below the line, *A B*, in Fig. 15. In cases where the sand is moist and not too gravelly, very little difficulty is ex-



ARCH TIMBERS SUPPORTING RAISED TUNNEL ROOF.

perienced in making the excavation for the width of a plank, but where the ground contains gravel, boulders or sharp sand, it is necessary to give some little protection to the outer face of this material while the next plank is being put in place. This protection is usually secured by using thin strips, such as barrel-staves or splinters, backed by hay used in the form of thatch. These splinters or barrel-staves may be pulled ahead as each plank is set in place.

Plate LXXII is a photograph of a section of tunnel braced by arch timbers, of five segments each. These timbers are 12 by 12-in. short-leaf pine, and are subjected to great stress in supporting a continuous section of the cast-iron roof (not shown in the photograph), which has been cut out and jacked up preparatory to the admission of a new lining. The writer believes that this form of timbering is the most substantial that can be introduced into tunneling.

The consideration of the questions contained in this paper has long been in the writer's mind, and he has at last decided to present them, for two reasons:

First, he believes that the subject of bracing and its relation to earth pressures is not properly provided for in the ordinary data and formulas, and he hopes, either in this paper or in the resultant discussion, that the question may be established beyond controversy, and on a basis which will be of practical value to engineers and contractors.

Second, he believes that insufficient consideration is given to the subject of bracing by engineers in general, it being ordinarily deemed sufficient to leave this question to more or less intelligent foremen; and, while it is not intended to impeach in any way the intelligence of any foreman, for whose opinion the writer has in many cases a very high regard, it is thought that the subject is one requiring more engineering consideration than is ordinarily given to it.

In conclusion, the writer wishes to thank George S. Rice, M. Am. Soc. C. E., of the Rapid Transit Railroad Commission; George H. Pegram, M. Am. Soc. C. E., of the Rapid Transit Subway Construction Company; and Mr. F. L. Cranford, of Cranford and McNamee, for the use of photographs, and for valuable suggestions.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

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A SOLUTION OF THE PROBLEM OF DETERMINING THE ECONOMIC SIZE OF PIPE FOR HIGH-PRESSURE WATER-POWER INSTALLATION.

Discussion.*

BY MESSRS. W. L. BUTCHER, W. E. BUCK, P. E. STEVENS, C. L. DEMOTT, E. KUICHLING, WILLIAM J. ROBERTS, CHARLES D. MARX, C. B. WING AND JAMES H. WISE.

Mr. Butcher.

W. L. BUTCHER, ASSOC. M. AM. SOC. C. E. (by letter).—The problem presented here is similar to the one encountered in the design of water and sewage disposal works, as to the most economical size of force main, for which the writer has worked out a formula.†

In regard to the problem under consideration, using the author's assumptions as to cost and perpendicularity of pipe, value of C, etc., a formula may be deduced, as follows:

Let x = the diameter of the pipe, in feet;
a = the head, in feet, on the section under consideration;
b = the cost of the pipe, in dollars per pound;
d = the value of the energy of 1 cu. ft. per sec. with a head of 1 ft.;
f = the total loss of friction in the above section;
Q = the quantity flowing, in cubic feet per second;
10 000 = the tensile stress in the steel, in pounds per square inch;
490 = the weight of 1 cu. ft. of steel, in pounds;

* This discussion (of the paper by Arthur L. Adams, M. Am. Soc. C. E., printed in *Proceedings* for May, 1907), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† *The Engineering Record*, May 13th, 1905.

then, the cost of a section of pipe 1 ft. long, under a head a = Mr. Butcher.
$\left\{\frac{\frac{62.4\ (a-f)\ x}{2}}{1\ 440\ 000}\right\}$ 490 $\pi\ x\ b$ (thickness of pipe shell neglected in calculating circumference) $= 0.033\ a\ b\ x^2 - 0.033\ f\ b\ x^2$;

also, $$V = c\sqrt{r\ s},$$

or $$\frac{Q}{\frac{\pi\ x^2}{4}} = c\sqrt{\frac{x}{4}\ s},$$

or $$s = \frac{0.00065\ Q^2}{x^5}.$$

Whence the value of the energy lost in passing 1 ft. of pipe $= \frac{0.00065\ Q^3\ d}{x^5}$.

For the most economical diameter of pipe, the cost of the pipe plus the value of the energy lost must be a minimum, or, in the terms of the calculus, the first differential of $0.033\ a\ b\ x^2 - 0.033\ f\ b\ x^2 + \frac{0.00065\ Q^3\ d}{x^5}$ should be placed $= 0$; that is,

$$0.066\ a\ b\ x - 0.066\ f\ b\ x - \frac{0.00325\ Q^3\ d}{x^6} = 0;$$

or, $$x = \sqrt[7]{\frac{0.0492\ Q^3\ d}{a\ b - f\ b}}.$$

By this equation the proper diameter at any point may be determined. In solving this equation, a value of f must be assumed, and afterward corrected, if necessary. However, considering the limitations of the formula, the value of f can usually be approximated near enough at the first trial.

TABLE 2.—EXAMPLE OF THE APPLICATION OF THE FORMULA TO AN ACTUAL CASE, WHEN THE VALUE OF ONE HORSE-POWER = $100; COST OF PIPE = $0.07 PER POUND; Q = 100 CU. FT. PER SEC.; AND HEAD = 1 000 FT.

Section.	Diameter, in feet.	Thickness of shell, in inches.	Weight of pipe, in pounds.	Cost.	Velocity, in feet.	Friction loss, in feet. $C = 100$.
0 to 200	4.5	$\frac{1}{4}$	29 000	$2 030	6.3	0.70
200 " 400	4.1	$\frac{5}{16}$	46 000	3 220	7.5	1.10
400 " 600	3.9	$\frac{3}{8}$	62 000	4 340	8.5	1.48
600 " 800	3.7	$\frac{7}{16}$	78 000	5 460	9.4	1.91
800 " 1 000	3.6	$\frac{1}{2}$	86 000	6 020	9.7	2.09
Totals....	.....	.....	.....	$21 070	.....	7.28

Mr. Butcher

The expression,

$$x = \sqrt[7]{\frac{0.0492\ Q^3\ d}{a\ b - f\ b}}, \text{ may be written as } a\ b\ x^2 - f\ b\ x^2 = \frac{0.0492\ Q^3\ d}{x^5};$$

or $$2\ (0.033\ a\ b\ x^2 - 0.033\ f\ b\ x^2) = \frac{5\ (0.00065\ Q^3\ d)}{x^5};$$

that is $2 \times$ cost of pipe $= 5 \times$ value of energy lost,

which is the same result as obtained by the author's graphical method.

With a head of 7.28 ft., 100 cu. ft. per sec. means a loss of 82.7 h. p., having a value of $8 270, or practically four-tenths of the cost of the pipe. Although in Table 2 it is assumed that the pipe is vertical, it will be observed that such an assumption is not necessary in order to apply the formula.

Mr. Buck.

W. E. Buck, M. Am. Soc. C. E. (by letter).—To develop a formula for this purpose, in addition to the nomenclature used by the author,

let Q = the discharge, in cubic feet per second;
L = the length of the pipe line, in feet;
D = the cost of the pipe line;
d = the diameter of the pipe, in inches;
b = the value of 1 h-p.;
B = the value of the power lost;
m, k, k', and f are constants, as explained below.

The cross-section of the pipe, in square feet $= \frac{\pi\ d^2}{576}$.

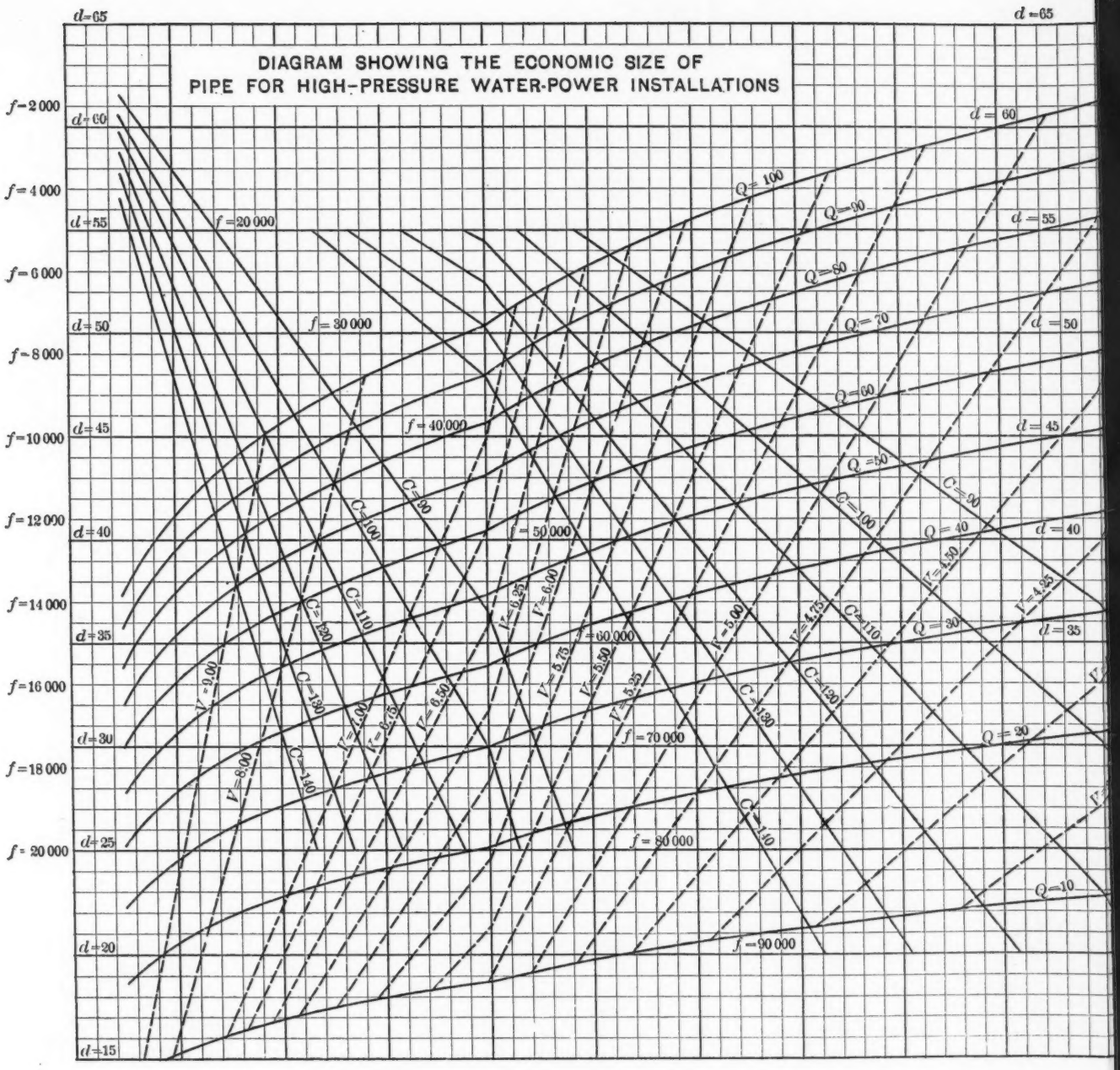
Hence $V = \frac{576\ Q}{\pi\ d^2}$.

$R = \frac{1}{4}$ the diameter, in feet, $= \frac{d}{48}$.

$$S = \frac{576^2\ Q^2}{C^2\ \pi^2\ d^4 \times \frac{d}{48}} = \frac{1\,613\,565\ Q^2}{C^2\ d^5}.$$

The total loss of head $= S\ L$; the loss of horse-power $= 0.1134\ Q\ S\ L$, and the value of the power lost $= 0.1134\ b\ Q\ S\ L$. Substitute the value of S, and $B = \frac{182\,978\ Q^3\ L\ b}{C^2\ d^5}$. Let $m = \frac{182\,978\ Q^3\ L\ b}{C^2}$ and $B = \frac{m}{d^5}$.

If the cost of the pipe line varies as the square of the diameter, $D = k\ d^2$; $B + D = \frac{m}{d^5} + k\ d^2$, and this is to be a minimum. Equate the first differential of this to zero, and $-\frac{5\ m}{d^6} + 2\ k\ d = 0$; from


DIAGRAM SHOWING THE ECONOMIC SIZE OF
PIPE FOR HIGH-PRESSURE WATER-POWER INSTALLATIONS
d=65
d=65
f=2 000
d=60
f=4 000
d=55
f=6 000
d=50
f=8 000
d=45
f=10 000
f=12 000
d=40
f=14 000
d=35
f=16 000
d=30
f=18 000
f=20 000
d=25
d=20
d=15
f=20 000
f=30 000
f=40 000
f=50 000
f=60 000
f=70 000
f=80 000
f=90 000
d=60
d=55
d=50
d=45
d=40
d=35
Q=100
Q=90
Q=80
Q=70
Q=60
Q=50
Q=40
Q=30
Q=20
Q=10
C=90
C=100
C=110
C=120
C=130
C=140
V=9.00
V=8.00
V=7.00
V=6.75
V=6.50
V=6.25
V=6.00
V=5.75
V=5.50
V=5.25
V=5.00
V=4.75
V=4.50
V=4.25

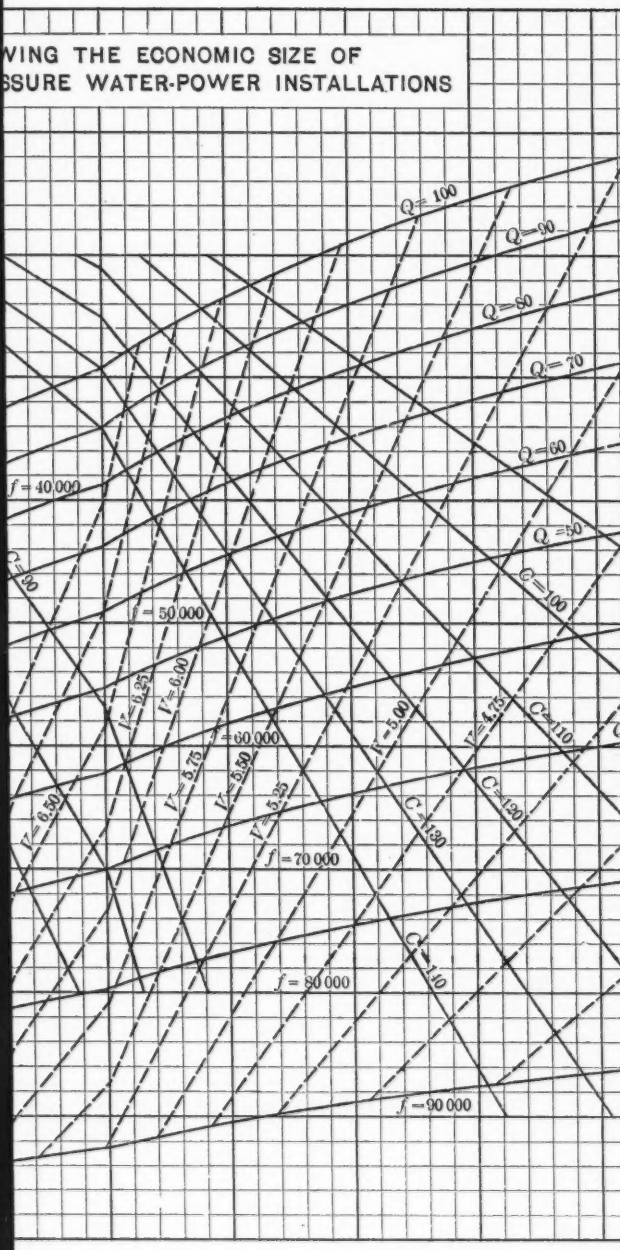
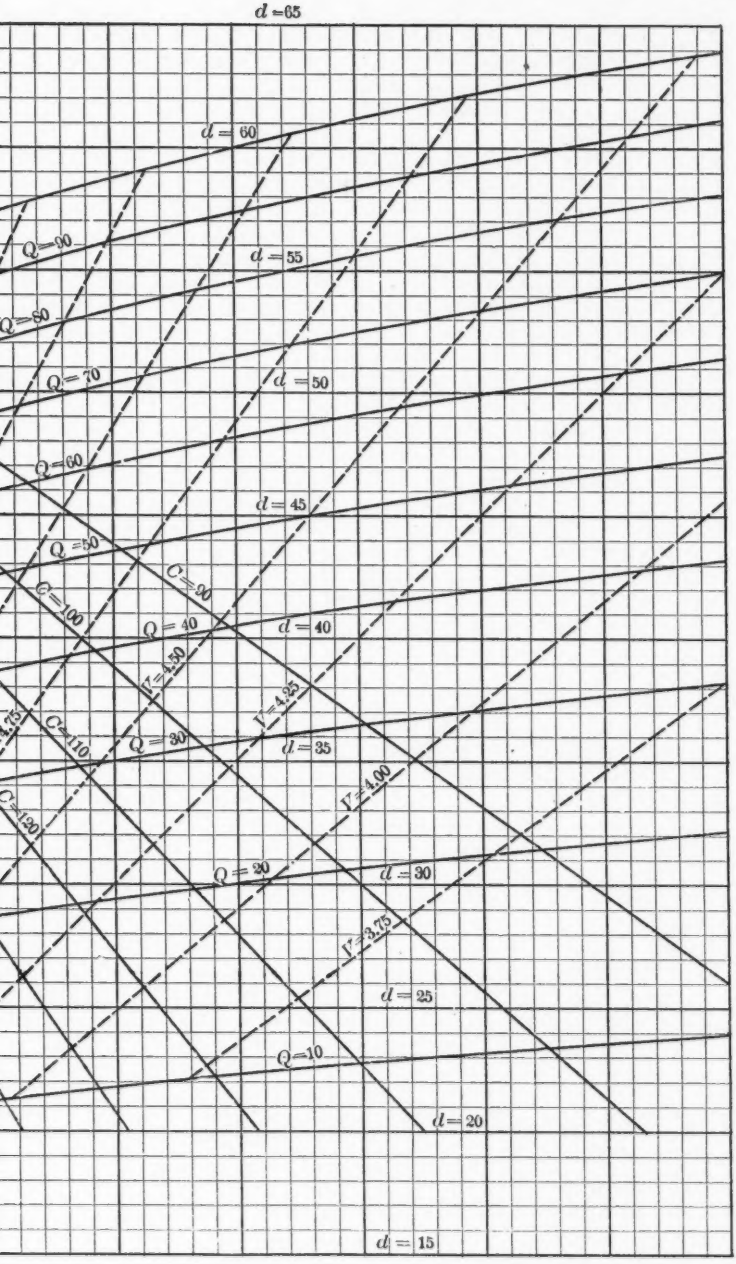

VING THE ECONOMIC SIZE OF
SSURE WATER-POWER INSTALLATIONS
Q=100
Q=90
Q=80
Q=70
Q=60
Q=50
f=40,000
f=50,000
f=60,000
f=70,000
f=80,000
f=90,000
C=100
C=110
C=120
C=130
C=140
r=6.50
r=6.25
r=6.00
r=5.75
r=5.50
r=5.25
r=5.00
r=4.75

PLATE LXXIII.
PAPERS, AM. SOC. C. E.
AUGUST, 1907.
BUCK ON
SIZE OF WATER POWER PIPE.



Mr. Buck.

which $d = \left(\frac{5\ m}{2\ k}\right)^{\frac{1}{7}}$. Substitute this value in the expressions for B and D, and $\frac{B}{D} = \frac{m}{\left(\frac{5\ m}{2\ k}\right)^{\frac{5}{7}}} \div k\left(\frac{5\ m}{2\ k}\right)^{\frac{2}{7}}$; which reduces to 0.4, the value given by the author.

Applying the formula, $d = \left(\frac{5\ m}{2\ k}\right)^{\frac{1}{7}}$, to the conditions represented in the diagram, Fig. 1, and the results are as follows:

For the conditions of Curve "A", $d = 47.78$
" " " "B", $d = 43.27$
" " " "C", $d = 52.75$
" " " "D", $d = 57.14$

These values agree with the diagram.

It should be noted that the values given by the author in Columns 8 and 9 of Table 1 do not follow exactly the formula given above, but they should, if the computations for loss of head were carried out sufficiently.

The cost of pipe per foot, as given in Column 7, does not vary exactly as the square of the diameter, because the author has proportioned the pipe to the dynamic head instead of the static head. There would seem to be no occasion for this, as the more the dynamic head falls below the static head the greater the danger from water hammer.

In the formula given above, L is a factor in the value of m, and also in the value of k. If $k = L\ k'$, so that $k =$ the cost per foot of pipe divided by the square of the diameter, $\frac{5\ m}{2\ k}$ reduces to $\frac{457\ 445\ b\ Q^3}{C^2\ k'}$, and $d = \left(\frac{457\ 445\ b\ Q^3}{C^2\ k'}\right)^{\frac{1}{7}}$. Let $\frac{b}{k'} = f$, and $d = \left(\frac{457\ 445\ f\ Q^3}{C^2}\right)^{\frac{1}{7}}$.

The diagram, Plate LXXIII, has been constructed from this formula, and is used in the following manner: Enter the diagram at the value of f, proceed horizontally to the right, to the line representing the proper value of C, then proceed vertically to the line representing Q, and the value of d is shown by the horizontal lines. For values of f ranging from 2 000 to 20 000, the C lines at the left must be used; and for values of f ranging from 20 000 to 90 000, those at the right must be used. The dotted lines show the velocities, in feet per second.

Mr. Buck.

The diagram may be used to design compound pipes. For example, suppose a pipe line to deliver 70 cu. ft. per sec., under 800 ft. head, and that the pipe is to be built in four sizes, and, further, assume $b = 110$ and $C = 120$.

By preliminary estimate, it is found that the average cost per foot of a 40-in. pipe will be:

For heads	0 to 200 ft.	$2.90,	for	which	$f = 60\,700$
" "	200 to 400 "	5.70	"	"	$f = 30\,900$
" "	400 to 600 "	9.75	"	"	$f = 18\,050$
" "	600 to 800 "	13.80	"	"	$f = 12\,750$.

Then, by the diagram, Plate LXXIII:

For head	0 to 200 ft.,	$d = 48.8$	and	$V = 5.4$
" "	200 to 400 "	$d = 44.4$	"	$V = 6.5$
" "	400 to 600 "	$d = 41.0$	"	$V = 7.7$
" "	600 to 800 "	$d = 39.0$	"	$V = 8.4$

The formula and the diagram are both based on the total theoretical power lost, and the value of b to be used should be the actual value of a horse-power at the wheels multiplied by the percentage of efficiency of the wheels.

The break in the curves of the diagram at the fourth heavy vertical line is occasioned by a change of horizontal scale to make the portion at the left of this vertical more easily used.

Mr. Stevens.

P. E. Stevens, Assoc. M. Am. Soc. C. E. (by letter).—The formula derived by Mr. Adams should prove very useful in this field, provided its limitations are kept clearly in mind. It is not sufficient to say that a design is the most economical, without stating the nature of the economy effected.

In planning to develop water-power from a given stream it is first necessary to ascertain what the proprietor of the rights wishes to derive therefrom in the way of benefits. It may be required to develop a given net power—within the capacity of the stream—at a minimum first cost or at a minimum annual cost; it may be required to develop a maximum of power at a sacrifice of cost per unit; it may be required to secure a maximum rate of income relative to the capital invested; or it may be required to secure the maximum net annual income from the stream in question. The problem of economy presents itself in a great variety of forms, and each requires different treatment. Of the cases just cited, each will be seen to be different from every other, and it is only to the last mentioned that the author's solution applies.

Mr. Adams offers as a major premise the self-evident statement that:

"The relation between the investment in any pipe line and the value of the energy lost in frictional resistance to flow is most

economical wherein the cost of pipe plus the value of the energy sacrificed is a minimum." Mr. Stevens.

The condition for a minimum value of cost of pipe plus the value of lost energy is then determined, and the conclusion is drawn as follows:

"That pipe fulfills the requirements of greatest economy wherein the value of the energy annually lost in frictional resistance equals four-tenths (0.4) of the annual cost of the pipe."

The inference is that economy in the relation of the investment in the pipe to the value of energy lost in frictional resistance is identical with economy in power development. The author does not seek to establish this identity in his paper, although it is essential to the logical development of his conclusion from the premises. If the conditions are as in the fourth case cited by the writer, namely, a desire on the part of the client to secure a maximum net annual earning capacity from his water rights, then, and then only, can this identity be established. The net annual value of the power delivered by the pipe line will be equal to the annual value of the total power of the stream—after deducting the annual cost of the impounding and head works—less the annual cost of the pipe plus the annual value of the power sacrificed. Therefore, in so much as the pipe affects the result, the annual net earnings will be a maximum when the latter mentioned sum is a minimum.

That this solution does not apply to the first case cited by the writer, may be seen by an inspection of Table 1. It will be noted that the cost of pipe line per horse-power developed is least for the smallest pipe and greatest for the largest, being nearly five times as great for the latter as for the former. In such a case, the pipe cannot be considered alone in determining conditions for greatest economy in cost for a definite horse-power, but must be taken in connection with the other works required, and its diameter must be adjusted to the head to be used.

In order to protect the busy engineer from the possibility of making a mistaken application of any rule of economy, the rule should be stated so as to define the nature of the economy effected. The valuable rule derived by Mr. Adams, following this idea, would result in a statement about as follows: In developing a water-power of fixed fall and flow, that pipe has the greatest net annual earning capacity wherein the value of the energy lost in frictional resistance is equal to four-tenths (0.4) of the annual cost of the pipe line.

It is the writer's opinion that the author's solution of this problem should give him no cause to regret the "loss" of his calculus. The laws of graphics are more easily retained in one's

Mr. Stevens. memory than those of the calculus. An engineer should be economical of his own mental energy as well as of his client's resources.

Mr. DeMott. C. L. DeMott, Assoc. M. Am. Soc. C. E. (by letter).—In the main, Mr. Adams has given some well-considered points, but the writer believes that in some instances he is misleading and incorrect.

The statement of the solution of the problem seems to be logical and correct, but the two statements—one as to the total cost and the other as to yearly cost—appear to be confused in his graphical solution.

By referring to the diagram, it appears that the most economical pipe would have a diameter less than 48 in., with steel at 7 cents per pound and "energy at $100 (per year) per horse power." By referring to Column 7 of Table 1, it appears that a 66-in. pipe would cost but $6 170 per thousand feet more than a 60-in. pipe. Now, if the allowance of 10% (used by Lord Kelvin) be used for interest and depreciation, this will give an increase in yearly cost of $617; while, from Column 8 of Table 1, it is noted that the annual saving in energy is $680. Whence it appears that a 66-in. pipe is more economical than a smaller one.

This conclusion is borne out by a mathematical solution of the problem. Using the statements and nomenclature of Mr. Adams:

Yearly cost of pipe $= a\,D^2$,

Yearly value of lost energy $= m\,S$,

where a and m are constants, and D is the diameter of the pipe, in feet. Substituting in the value of S the value of V in terms of D and the given quantity of water, we have:

$$\text{Yearly value of lost energy} = \frac{b}{D^5},$$

where b is a new constant.

Hence, by the conditions, $\dfrac{b}{D^5} + a\,D^2$

must be a minimum, or, $-\dfrac{5\,b}{D^6} + 2\,a\,D = 0.$

Whence, $$D = \sqrt[7]{\frac{5\,b}{2\,a}}.$$

From the values used by Mr. Adams,

$$a = 115,$$

$$\text{and } b = 7\,500\,000,$$

which gives $$D = 5.564 \text{ ft.}$$

This problem, however, can be solved most readily by the "cut and try" method. The pipe manufacturers use only certain thicknesses of metal, and make certain shop sizes of pipe. After cal-

culating the cost of two sizes of pipe, which are thought to be most nearly correct, and making a comparison of the value of the energy saved, a pretty fair indication of the most economical size will be given. An hour's additional work will solve the problem. Mr. DeMott.

If Mr. Adams will plat his curves representing the yearly cost of pipe, and the yearly value of wasted energy, on the same axis, he will observe that the least value, of the curve formed by adding the two sets of values, will be quite near the point where the separate values are equal, the method perhaps used by Lord Kelvin in the solution of his problem.

E. KUICHLING, M. AM. SOC. C. E.—This subject is of much interest, and the author has presented a mode of solution that seems to be very simple. His fundamental proposition is that the most economical diameter of a pressure pipe is the one which will make the sum of the total cost of the pipe line and the value of the head lost in overcoming the frictional resistances in such pipe a minimum; and, without any further explanations and definition of what is meant by the value of the head lost by pipe friction, he states that this proposition is self-evident. Mr. Kuichling.

In the speaker's opinion, the proposition is not self-evident, but requires considerable thought; and as to the value of the power lost by pipe friction, much room for explanation is open. It may be inferred that the value of $100 and $50 per horse-power, used by the author in Table 1 and his diagram, Fig. 1, is the capitalized value of the difference between the price paid by the consumer per horse-power per year and the cost of the operating expenses, maintenance and depreciation for producing one horse-power per year with the plant under consideration. This difference represents the annual interest and profit on the investment of capital or cost of construction per horse-power. If the aggregate of such interest and profit be taken at 10%, and the difference between the selling price and said cost of production per horse-power per year is $10, the value of each horse-power lost by pipe friction will be $100; and, similarly, if that difference is $5, the value of each horse-power so lost will be $50.

With this definition of the value of each horse-power capable of development at the given site the speaker is in accord, but as the difference between said price and cost is by no means constant in different localities, a uniform figure cannot be adopted. The value of the power lost by pipe friction, therefore, will vary with the special conditions pertaining to each plant, and must be estimated after a plan for the work has been made and its approximate cost and prospective revenue have been ascertained.

When the available quantity of water, Q, in cubic feet per second, is fixed, the determination of the most economical diameter, d,

Mr. Kuichling.

for the pipe becomes essentially a problem of transportation, into which only two elements enter. The first is the cost of the pipe line, which is obviously a certain function of the diameter, and the second is the capitalized cost of overcoming the resistances to the transportation or motion of Q, which is the value of the power lost by the friction head, h_x. The virtual cost, U, of transporting Q through the pipe is the sum of these two costs; and as the friction head, h_x, can be expressed in terms of Q and d, it follows that U is a definite function of d. The problem is then to find that value of d which will make U a minimum.

The cost of the pipe conduit per linear foot, as given in Table 1, is very closely expressed by the formula:

$$y = 0.9043d^2 + 2.3076d - 4.592, \text{ in dollars,}$$

wherein d is the diameter of the pipe, in feet; and, if the length is denoted by l, the cost of the conduit will be $l\,y$ dollars. Based on the Chezy formula, the friction head is $h_x = \left(\frac{8}{\pi}\frac{Q}{c}\right)^2 \frac{l}{d^5}$, and with a turbine of 80% efficiency this friction head represents the expenditure of $N_x = \frac{Q\,h_x}{11}$ horse-power for moving Q through the pipe; and if the capitalized value of the energy so expended is at the rate of S dollars per horse-power, as aforesaid, its virtual cost will be $= S\,N_x$ dollars. The entire cost of transporting Q, therefore, is:

$$U = l\,y + S\,N_x = l\,(\alpha d^2 + \beta\,d - \gamma) + \frac{S\,Q}{11}\left(\frac{8}{\pi}\frac{Q}{c}\right)^2 \frac{l}{d^5} \cdots (1)$$

To find the value of d which will make U a minimum, place the first differential coefficient of U with respect to d as a variable equal to zero, thus obtaining, finally:

$$d = \left[\frac{2.9475\,S}{(2\,\alpha\,d + \beta)\,c^2}\right]^{\frac{1}{6}} \sqrt{Q} \cdots\cdots\cdots\cdots\cdots (2)$$

It will be noticed that d also appears in the denominator of the second member of Equation 2, and hence the solution must be obtained by trial. As a preliminary value for d in the second member, assume that which corresponds to a velocity of about 6 ft. per sec., or $d = 0.46\sqrt{Q}$, and thence deduce a first approximation by solving the equation. The result may then be used in the second member, thus obtaining a second approximation which may be sufficiently accurate for all practical purposes.

For the case given by the author, we have $\alpha = 0.9043$, $\beta = 2.3076$, $c = 100$, $Q = 100$, and $S = 100$ as one value and 50 as another. Taking $d = 0.46\ \sqrt{Q} = 4.6$ as a preliminary value for use in the second member of Equation 2, there follows with $S = 100$:

$d = 0.375\ \sqrt{Q}$ as a first approximation, and thence $d = 0.384\sqrt{Q}$ as a second approximation. With $S = 50$, and a preliminary value of $d = 3.5$, there follows $d = 0.346\ \sqrt{Q}$ as a sufficiently close approximation. Mr. Kuichling.

If the cost of the pipe conduit per linear foot be expressed by $y = \alpha\, d^2$, as contemplated by the author, the value of α will be approximately 1.1667 according to Table 1. Equation 1 will then become:

$$U = l\,\alpha\,d^2 + \frac{S\,Q}{11}\left(\frac{8\,Q}{\pi\,c}\right)^2 \frac{l}{d^5} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

and by placing the first differential coefficient equal to zero, as before, there follows:

$$2\,l\,\alpha\,d - \frac{5\,S\,Q}{11}\left(\frac{8\,Q}{\pi\,c}\right)^2 \frac{l}{d^6} = 0,$$

or
$$2\,[l\,\alpha\,d^2] = 5\left[\frac{S\,Q}{11}\left(\frac{8\,Q}{\pi\,c}\right)^2 \frac{l}{d^5}\right]$$

or 2[cost of pipe conduit] = 5[value of head or energy lost], whence the author's proposition that the most economical diameter is that for which the value of the head or energy lost by frictional resistances is four-tenths of the cost of the pipe conduit.

From the last equation we also find the required value of the diameter in terms of S and Q:

$$d = \left(\frac{1.4738\,S\,Q^3}{\alpha\,c^2}\right)^{\frac{1}{7}} = \left(\frac{1.4738\,S}{\alpha\,d\,c^2}\right)^{\frac{1}{6}} \sqrt{Q} \quad \ldots\ldots (4)$$

The foregoing demonstration makes the economical diameter, d, in any given case depend mainly on the value of Q, which is more convenient for practical use. For $\alpha = 1.1667$, $c = 100$, and $S = 100$ and 50, we will have, respectively: $d = 0.536 Q^{\frac{3}{7}}$ and $0.485\ Q^{\frac{3}{7}}$; and with $Q = 100$ there follows, respectively: $d = 3.8541$ and 3.4908, or substantially the same as found above with a different expression for the cost of the pipe conduit.

It may also be added that the cost, y, of the pipe conduit per linear foot, as given above, is not generally applicable, but should be regarded as adapted only to a particular locality. In other cases, where the fall is different, the values of the factors, α and β, will be greatly modified.

WILLIAM J. ROBERTS, ASSOC. M. AM. SOC. C. E. (by letter).— The author has presented a "rule defining the true economic relation to be observed in designing pipes for high-pressure water-power installations * * * the volume of discharge * * * being fixed," that may be verified readily when the equation of the curve is known. Mr. Roberts.

Mr. Roberts.

This equation may be deduced as follows:

Cost of pipe per foot, steel at \$0.07 per lb. $= 1.17D^2 - \frac{7.7}{D^3}$, in which D is the diameter, in feet, the result being expressed in dollars.

For velocities below 10 ft. per sec., the final term may be neglected without sensible error. The equation then becomes:

$$x = 1.17D^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The energy lost in 1 000 ft. of pipe $= 0.4 \frac{v^2}{D} = \frac{6\,500}{D^5}$.

The value of the energy lost in 1 000 ft. of pipe at \$100 per horse-power $= \frac{6\,500}{D^5} \times \frac{100}{8.8} \times 100 = \frac{7\,380\,000}{D^5}$.

For convenience, this may be written:

$$y = \frac{7\,380\,000}{D^5} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Eliminating D between Equations 1 and 2, there results:

$$x^{\frac{5}{2}}\, y = 10\,900\,000 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

which is the required equation of the curve.

Differentiating this equation:

$$\frac{5}{2}\, x^{\frac{3}{2}}\, y\, d\, x + x^{\frac{5}{2}}\, d\, y = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Whence

$$\frac{d\, y}{d\, x} = -\frac{5\, y}{2\, x} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

which is the slope of the tangent to the curve at any point the co-ordinates of which are x and y. This tangent makes an angle of 135° with the x-axis.

The tangent of 135° is —1, hence,

$$\frac{d\, y}{d\, x} = -\frac{5\, y}{2\, x} = -1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

$$5\, y = 2\, x \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

$$y = 0.4\, x \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

which was to be proven.

The coefficients and constants in Equations 1, 2, and 3 are based upon pipe at 7 cents per pound, and energy at \$100 per horse-power, their values being determined with the slide-rule. Inasmuch as the character of the curve in Equation 3 is independent of the magnitude of the constant, this form of the equation will apply to any price for pipe, or any value of the energy lost. This is the more readily seen in Equation 4, where the second member becomes zero.

Hence the rule is established.

CHARLES D. MARX and C. B. WING, MEMBERS, AM. SOC. C. E. (by letter).—The following is a mathematical verification of the rule formulated by Mr. Adams: Messrs. Marx and Wing.

It is assumed that the yearly income will vary as the horse-power output per annum multiplied by the value per horse-power at the generating station, less the interest on the cost of the pipe line.

Let I = the annual income;
h = the total head;
h_1 = the head lost in friction;
d = the diameter of the pipe;
r = the rate of interest per annum;
k = receipt per horse-power per year.

Then, the total horse-power delivered at the generating station $= f(h-h_1)$, in which f is a constant. The weight, and therefore the cost, of the pipe will vary approximately as $f_1 d + f_2 d^2$ (in which f_1 and f_2 are constants) as we cannot start with zero as the thickness of the pipe.

The head lost in friction will vary as $\frac{f_3}{d^5}$, in which f_3 is a constant.

Therefore, $$I = k f (h - h_1) - r (f_1 d + f_2 d^2).$$

$$I = k f h - \frac{f f_3 k}{d^5} - r f_1 d + r f_2 d^2.$$

$$\frac{d I}{d d} = \frac{5 f f_3 k}{d^6} - r f_1 - 2 r f_2 d.$$

Equating to zero:

$$\frac{k f f_3}{d^5} = \frac{1}{5} r f_1 d + \frac{2}{5} r f_2 d^2,$$

or, approximately, the capitalized value of the annual loss of horse-power should be four-tenths of the cost of the pipe line.

JAMES H. WISE, ASSOC. M. AM. SOC. C. E. (by letter).—The subject of this paper is of considerable interest and great importance in the design of high-pressure pipe lines for hydro-electric installations. This problem was given careful consideration by F. G. Baum, Assoc. M. Am. Soc. C. E., formerly Chief Engineer of the California Gas and Electric Corporation, and the writer, in considering the design of pressure pipe lines installed by the above corporation. A mathematical analysis of the problem (herewith submitted) was made, the result agreeing with that obtained graphically by Mr. Adams. Mr. Wise.

When this problem was originally taken up, the general formula, $h = \frac{f l v^2}{2 g d}$, for head loss was used; but, for ease of comparison in

Mr. Wise. this discussion, the equation, $S = \frac{V^2}{C^2 R}$, will be used; the deduction, of course, being the same. For obtaining a simple expression for power loss, due to pipe friction, the following equations and assumptions were taken:

$S = \frac{V^2}{C^2 R}$, Friction head loss in the pipe;

C = Pipe coefficient, taken as constant;

$R = \frac{D}{4}$, Hydraulic radius;

$V = \frac{Q}{A}$, Velocity, in feet per second;

Q = Quantity of water, in cubic feet per second;

D = Inside diameter of the pipe;

$A = \frac{\pi D^2}{4}$, Area of the pipe.

Eliminating all variable factors except D, by substitution in terms of D, we have, $S = \frac{64 Q^2}{C^2 \pi D}$; but the power loss, $P = Q \rho S$, where $\rho = 62.5$ lb., the weight of 1 cu. ft. of water. If e is the value of power per foot-pound per second, for one year, the value of the annual power loss, L, may be expressed as $L = e P = \frac{64 \rho e Q^3}{C^2 \pi D^5}$; but, as all terms except D in the last member of the equation may be considered constant, the equation may take the form, $L = \frac{K}{D^5}$.

To obtain the annual cost of the pipe, I, the following assumptions were made:

t = Thickness of metal;
πD = Circumference of pipe;
w = Weight of metal per cubic inch;
i = Annual interest cost of metal per pound.

Therefore, $I = \pi D t w i$, but, for any pressure, the thickness of the pipe varies as the diameter, or, in the form of an equation, $t = m D$, where m is a constant depending upon head and safe stress assumed. Eliminating t, we have $I = \pi D^2 m w i$, but all terms in the second member of the equation are constant except D, the equation, therefore, may be expressed, $I = N D$, N being a constant.

The problem now is to make T, the annual cost of the pipe, I, plus the annual value of the power loss, L, a minimum, or, expressed as an equation, $T = I + L = N D^2 + \frac{K}{D^5}$, to be a minimum; but, by

the familiar rule of calculus, this obtains when the first derivative of T with respect to D is equal to zero. Mr. Wise.

$$T = N D^2 + \frac{K}{D^5}.$$

$$\frac{d T}{d D} = 2 N D - \frac{5 K}{D^6} = 0,$$

or

$$2 N D = \frac{5 K}{D^6}.$$

Multiplying both sides of the equation by $\frac{D}{5}$, we have $\frac{2}{5} N D^2 = \frac{K}{D^5}$. Therefore, T is a minimum when $\frac{2}{5}$ or 0.4 of the annual cost of the pipe equals the yearly value of the power loss; or, it may be expressed in words, as Mr. Adams has done in his paper.

It is found, invariably, that in the mathematical discussion of practical problems, assumptions must necessarily be made which will sacrifice theoretical exactness, and, in connection with this, the writer calls attention to the fact that, in addition to assuming C to be constant for all diameters of pipe, in using D for the inside as well as the mean diameter of the pipe and other approximations, it is also making a broad assumption to state that the cost of riveted steel pipe is proportional to the square of the diameter; nor does the over-weight due to lap straps and rivet heads bear a constant relation to the weight of the net pipe cylinders. In this it may be noted that with thin metal, say $\frac{7}{16}$ in. or less, where a lap joint of about 70% efficiency is used, the over-weight due to laps and rivet heads may vary from 4% to 15%, depending upon the diameter of the pipe, while, with thick metal, say about $\frac{7}{8}$ in., where a triple-riveted, double-welt, butt joint, developing about 85% of the plate, is generally used, the over-weight due to straps and rivet heads may vary from 20% to 45%, depending upon the diameter of the pipe. It may be noted, further, that the price per pound is not constant, it being less for large pipes of thin metal than for small pipes of thick metal. This is largely due to the higher shop costs in rolling and assembling heavy sheets.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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THE EFFECTS OF THE SAN FRANCISCO EARTHQUAKE OF APRIL 18TH, 1906, ON ENGINEERING CONSTRUCTIONS.

REPORTS OF A GENERAL COMMITTEE AND OF SIX SPECIAL COMMITTEES OF THE SAN FRANCISCO ASSOCIATION OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Discussion.*

BY MESSRS. EUGENE W. STERN, J. K. FREITAG, W. W. HARTS, E. A. RIX, W. F. WHITAKER, A. M. BIENENFELD, ARTHUR L. ADAMS, S. G. HINDES, LOREN E. HUNT, EDWIN DURYEA, JR., BERNARD BIENENFELD, J. P. CARLIN, CHARLES E. GOAD, R. B. GREEN, C. E. MOORE, AND A. L. A. HIMMELWRIGHT.

Mr. Stern. EUGENE W. STERN, M. AM. SOC. C. E.—The information gathered by the various committees is of the greatest value, especially because, for the first time in history, the effects of a very severe earthquake on tall, modern, steel-frame buildings have been made manifest.

Moreover, in view of the recent disastrous experiences at Valparaiso and Kingston, with the attendant loss of life and property, the subject is a timely one, and the thanks of the profession are due to the gentlemen who have so carefully and thoroughly studied the subject at first hand, and given the results of their investigations in these reports.

*This discussion has been continued from May, 1907, *Proceedings*. Additional discussions received prior to September 15th, 1907, will be published subsequently in *Transactions*.

Mr. Stern.

The Committee on Geology makes some statements that do not seem to be entirely in accord with the conclusions of the Committee on Buildings. It states:

"The damage to buildings, while large, was confined to those faulty either in design or in construction."

And:

"The results, so disastrous to buildings and engineering structures, can and will be provided against in the future."

This statement is not concurred in by the Committee on Buildings, which, in its report, says:

"Obviously, the shock may range from a tremor to that of a violence that would wreck any building."

And also:

"Should the earth-slip take place beneath a building, it would be wrecked."

To prove that the quality of workmanship, while important, is still not sufficient to prevent a disastrous wreck, the Committee on Buildings cites the case of St. Patrick's Academy, in which the brick walls were so well laid up in Portland-cement mortar that the walls invariably broke through the brick instead of the mortar joints.

The first thought that comes to one's mind is that a limit should be placed on the height of buildings. The higher the building, the more disastrous must be the whipping and gyratory effect of the earthquake. It is to be regretted that the Committee on Buildings makes no recommendation on this point.

It reports that while the injury to steel frames in buildings of Type 4 (in which the entire structure, including brick walls, was carried on the steel frame) was inconsiderable, the enclosing walls of brick or mortar were damaged to a greater or less extent, and will require extensive repairs. It cites the case of the Claus Spreckels Building, in which the stonework was badly worked on the beds above the tenth story; also that of the Chronicle Building and others in which the brick, stone, and terra-cotta work were badly cracked. While it recommends that for rear walls reinforced concrete offers the best solution, the reinforcing members being tied to the steel frame, it is illogical in recommending that the fronts be made of brick, terra cotta or stone tied to the steel frame, in so far as its own report shows that the motion of the earth tended to shatter the bond in brick and mason work.

If brick and masonry walls shake loose during an earthquake shock, let these materials be abandoned for something better.

It would be of great interest to know what damage resulted to buildings of Type 4, which were located on or near the fault line. The reports have not mentioned any cases of this kind.

Mr. Stern. As a class, the steel frame seems to have been the only form of construction that came through the earthquake at all satisfactorily, although the Committee reports damage to structural frames that will have to be repaired.

It states that the prime requisite of the structure is elasticity, which is reasonable; but should not provision also be made for inequality of settlement of foundations, as well as the vibratory effect of the quake? It is not always certain, in earthquake shocks, that the soil under foundations will not settle.

The speaker cannot conceive that a thoroughly rigid structure is the right one to build, but rather one that is designed for vibratory and swaying motion, and, at the same time, has sufficient flexibility in the joints, so that in case of unequal settlement of foundations it can be repaired at very much less expense than one in which no allowance for this has been made.

Regarding foundations, the Committee states that no instances of damage have come to its notice. Does this mean that there has been no unequal settlement of foundations, or that none of the foundation piers have been shattered, or what is the meaning? The speaker would recommend that isolated piers be firmly tied together at the level of the bottoms of columns.

The catastrophes at San Francisco and Kingston are still fresh in our minds, but there have been other very destructive earthquakes in comparatively recent times, and it might be well to review briefly some of the most disastrous of these.

In 1822, in Chili, an earthquake shook the coast for a distance of 1 200 miles north and south, and the coast line was elevated from 4 to 5 ft. for a distance of 35 miles.

In 1835 and 1837, also in Chili, there were disastrous earthquakes in which towns were destroyed and the coast was raised to a height of from 4 to 8 ft. for a distance of more than 100 miles.

In 1891, in the Provinces of Mino and Owari, in Japan, a severe earthquake occurred in which 7 000 people lost their lives and 17 000 were wounded, 197 000 houses were wholly demolished and 78 000 more than half demolished. A fault occurred, which extended entirely across the island, the vertical displacement being from 9 to 18 ft. and the horizontal displacement about 6 ft. A levee was moved bodily 60 ft., carrying a thicket of bamboo and pine trees. The area shaken was estimated at approximately 95 000 sq. miles.

In 1897, in the Provinces of Bengal and Assam, in India, there was an earthquake the effects of which extended over 1 750 000 sq. miles, many dislocations of the earth taking place, both vertical and horizontal, amounting in some places to 30 ft. The violence was so excessive that not a masonry structure in a district covering 6 000 sq. miles was left standing. Monuments and tombstones were de-

stroyed, and trees 6 and 7 in. in diameter were broken through the trunks by the swaying motion of the earth. Mr. Stern.

The recent earthquake at Valparaiso, in August, 1906, caused a loss of more than $250 000 000 in property, and destroyed, besides, 140 smaller towns and villages. More than 1 000 people lost their lives.

In January, 1907, the City of Kingston, Jamaica, was destroyed, the loss of life being about 1 000.

The Province of Guerrero, Mexico, in April, 1907, was visited by an earthquake which destroyed several towns and caused a loss of life of more than 100.

M. de Montessus de Ballore has tabulated the number of seismic occurrences which have been observed during the nineteenth century, amounting to the enormous total of 131 292 quakes, and 10 500 epicentra.

In view of the foregoing facts, it must be admitted by the candid student that the problem of constructing buildings in earthquake districts so as to withstand entirely the violence of some of the excessive seismic disturbances is a difficult one.

Destruction of property cannot be prevented, but the excessive loss of life and property through the improper construction of buildings can and should be very largely reduced.

It is an engineering possibility to design a structure—a ship, for instance—that will stand any kind of strain, and adapt itself to all manner of conditions. It is also an engineering possibility to design a building so that it will stand a great deal of shock, besides some inequality of settlement of foundations due to a distortion of the earth supporting it.

A proper adaptation of such structures to the needs of those occupying them is a modifying condition which, together with the architectural requirements, has to be considered in the problem. Primarily, it is a question of applying sound engineering principles to the question in hand, and architectural features should be subordinated to these.

The important lessons of the San Francisco disaster, as regards the construction of buildings in earthquake districts, seem to the speaker to be:

1.—That buildings should not be constructed more than 100 ft. in height.

2.—That all structures in the business sections of the city should be fire-proof.

3.—That fire-proof structures should have a frame in the design of which swaying and gyratory motions, as well as unequal settlement of foundations, should be provided for; and that this frame should carry the walls at every floor.

4.—That the best material thus far known for such a frame is steel.

Mr. Stern. 5.—That the floors, walls, and partitions should be of reinforced concrete in which the reinforcing members are securely tied to the steel frame.

6.—That the water and gas pipes, and electric wires, should have special ducts, and the practice of carrying these next to the columns and surrounded by their fire-proof covering cannot be too strongly condemned. There should be expansion joints in the water and gas pipes, in order to avoid breakage in case of settlement of the building.

Mr. Freitag. J. K. FREITAG, ASSOC. M. AM. SOC. C. E.—Referring to the "Report of the Committee on Fire and Earthquake Damage to Buildings," especially that portion dealing with the fire damage, it would seem that certain broad and vital principles relating to fire-resistive construction in general have not been sufficiently emphasized, but have been made of secondary importance to descriptions of damage of mere structural detail, and to consequent recommendations deduced therefrom.

The first conclusion* of the Committee is:

"Any deductions from the fire must be those based upon a general conflagration, and not those of an isolated fire. In view of the complete destruction of all materials it becomes a question as to what should be done to make a building fire-proof."

This conclusion, although somewhat amplified in a succeeding paragraph, which will be discussed later, seems to place altogether too much emphasis upon the possibility of making an individual structure fire-resisting under conflagration conditions. Previous conflagrations, notably that of Baltimore, have shown the almost utter futility of attempting to cope with fire when once it has reached the proportions of what is generally called a conflagration. No structural materials of which we have present knowledge are equal to the task of resisting successfully such severe test conditions, at least to a point which would justify any reliance which might be placed upon their use.

Further, if the high temperatures, the multitudinous points of attack, and the general impotence of all fire-fighting measures obtainable during a conflagration are to be entirely overcome, then the task of fire-resistive construction is surely a hopeless one, and those interested in fire-resistive principles might well be dismayed at the records of Baltimore and San Francisco. The Committee evidently realized this aspect of the question, for it states that:†

"Unless one has been an eye-witness, it is difficult to realize how all materials that men make into the shape of buildings can be so utterly destroyed in a general conflagration."

If, then, that fact is once admitted, as it must surely be by those thoroughly familiar with the tests of fire-resistive methods afforded

* *Proceedings*, Am. Soc. C. E., for March, 1907, p. 332.

† *Proceedings*, Am. Soc. C. E., for March, 1907, p. 328.

Mr. Freitag.

by the Baltimore and San Francisco conflagrations, the main question becomes, not so much what can be done to make any particular building fire-proof, using this or that detail of concrete or terra cotta, or one or another construction of exterior walls or partitions, etc. (though all these points are of immense value as details of the larger problem), but what can and should be done to prevent conflagrations? The Committee's answer to this most vital problem of the American people is far from satisfactory.

Statistics as to the annual fire losses in the United States are probably familiar to all who are interested in building construction. Let it suffice here to recall a few figures. The fire loss in the United States has now approximated $200 000 000 annually for several years, during normal conditions, *i. e.*, years which have not included widespread conflagrations. Add to this direct loss the expense of maintaining fire departments, etc., and the money paid to fire insurance companies in the way of premiums, and it is questionable whether these financial losses do not equal, or even surpass, the value of all new buildings erected throughout the United States within the year for which the comparison is made. Including the San Francisco conflagration loss, the year 1906 becomes an abnormal one, and the fire-waste alone, not counting fire departments or insurance premiums, is estimated at not less than about $506 000 000, while the estimated value of new building operations in the United States for the same year probably approximates $575 000 000. Hence no more vital economic problem is before our people to-day than the lessening of this stupendous drain.

Before considering the responsibility which lay before the community of San Francisco in making impossible a repetition of at least their share of this fire loss, or the same responsibility which lies before all cities, it will be pertinent to inquire into the conditions which made this great calamity (by fire) possible.

The report of the Committee states that:

"San Francisco was built probably in about the same way as other cities. It is an error to say that it was a wooden-frame city, as the business district was generally composed of buildings with brick walls. In among these had been constructed the so-called fire-proof structures, exposed on all sides to danger by the burning of the inflammable structures around them."

That San Francisco was not considered by insurance interests to be built "in about the same way as other cities," is made most clear in the Report on the City of San Francisco, issued in October, 1905, by the "Committee of Twenty" of the National Board of Fire Underwriters. The general summary of that report, page 64, reads as follows:

"Conflagration Hazard.—*Potential Hazard.*—In view of the exceptionally large areas, great heights, numerous unprotected

Mr. Freitag.

openings, general absence of fire-breaks or stops, highly combustible nature of the buildings, many of which have sheathed walls and ceilings, frequency of light wells and the presence of interspersed frame buildings, the potential hazard is very severe. *Probability Feature.*—The above features combined with the almost total lack of sprinklers and absence of modern protective devices generally, numerous and mutually aggravating conflagration breeders, high winds, and comparatively narrow streets, make the probability feature alarmingly severe.

"SUMMARY.—While two of the five sections into which the congested value district is divided involve only a mild conflagration hazard within their own limits, they are badly exposed by the others in which all elements of the conflagration hazard are present to a marked degree. Not only is the hazard extreme within the congested value district, but it is augmented by the presence of a compact surrounding great-height, large-area frame residence district, itself unmanageable from a fire-fighting standpoint by reason of adverse conditions introduced by the topography. In fact, San Francisco has violated all underwriting traditions and precedent by not burning up. That it has not done so is largely due to the vigilance of the fire department, which cannot be relied upon indefinitely to stave off the inevitable."

The last sentence of this summary has proved only too true a prophecy of the calamity which followed only a few months after the publication of this report.

In discussing particularly the congested-value district, which contained about 2 100 buildings, *Insurance Engineering* gave the following summary of the types of building construction:

Fire-proof.....	2.2 per cent.
Brick and wood joist.....	68.3 " "
Frame construction.....	29.5 " "

In further description of this area, the same journal stated as follows:

"In the congested value district there was but one sprinkler equipment and it was practically obsolete. One hundred and twenty buildings contained stand-pipes and hose, and a few small fire pumps drawing from deep wells. * * * All the fire-proof buildings had windows unprotected, and in many cases were badly exposed. About 50 per cent. of the joisted brick buildings had furred and wood-sheathed walls and wood-sheathed ceilings. * * * Large, open light wells were numerous, and conspicuously prominent on account of their size and number. Several of the older hotels were literally perforated with them. * * * About 90 per cent. of the entire city and 30 per cent. of the business section were of frame construction, brick buildings being confined almost entirely to the fire limits, and San Francisco could be justly termed a wooden city."

The above criticisms of San Francisco's buildings would be severe enough—indeed far too severe to be pleasant, as applied to any

large city—but, when applied to a city in a locality subject to seismic disturbances, the facts become a severe indictment, and show either the indifference of San Francisco's citizens, or the ignorance or carelessness of the Building Department. Municipal regulations (whether or not in a locality subject to earthquakes) which permit 30% frame construction within a congested-value district, which permit buildings of masonry walls and timber floors and partitions to be eight stories, or 100 ft., high, which permit "large private hotels and apartment houses of this type," which provide no limitations as to undivided areas, and which allow the "absence of modern protective devices generally," are most certainly insufficient, short-sighted, and unjust, and most particularly unjust to those investors who improve their property by erecting steel-skeleton fire-and-earthquake-resisting buildings, and then have them "exposed on all sides to danger by the burning of the inflammable structures around them." Mr. Freitag.

This brings up the consideration of civic responsibility, as applied to building construction. European cities long ago learned the lesson that safety to the individual means safety to the whole community, and *vice versa*. Witness the most ineffectual fire departments in most continental cities, and, withal, the trifling fire-losses, and, especially, the almost total absence of conflagrations, or even the spread of fire to immediately adjoining property in the cities of civilized Europe. The reason is to be found entirely in the matter of building construction. A building which will prove a menace to neighbors cannot be erected, and the responsibility of the individual as affecting the community is even carried so far in some localities of Europe that the owner of property causing fire damage to neighbors is held financially responsible for such loss.

It is just some such civic responsibility which is needed, and needed very soon, in all large American cities. Responsibility of the individual to the community, which will cause the individual to contribute to the public safety in matters of building construction by erecting structures which will not prove a menace to his neighbors; and responsibility of the community to the individual, in that those investors who improve their land by the erection of costly and permanent structures shall not be allowed to suffer constant hazard through irresponsible neighbors who have no thought or care of their civic duties.

It is now a trite saying that "fire-proof buildings must stand in fire-proof cities," but this statement contains the whole truth of the matter of fire-resistance. If American cities are not to suffer such conflagrations as have occurred at Chicago, Boston, Paterson, Baltimore, and San Francisco, besides many other lesser ones; if the realization of this tremendous financial drain is once grasped in an effort to lessen it; if it be admitted that isolated buildings surrounded by severe risks cannot withstand conflagration conditions, then the

Mr. Freitag. achievement of fire-proof cities (or at least the congested areas therein) must be made possible by uniform fire-resisting construction throughout.

Touching upon this point the Committee states as follows:

"The only statement that can be offered is that the best insurance for buildings would be the isolation of a district containing nothing but fire-proof structures. A general conflagration would then be impossible. Manifestly, this is impossible in San Francisco, where business must be resumed with the least cost. In many cities, it would be good insurance for men owning large buildings to combine to buy out old and inflammable structures, either demolishing or rebuilding them. Otherwise, there remains the danger of general conflagrations, such as those at Baltimore and San Francisco, in which fire-proof buildings will be injured from 30 to 60 per cent."

With the first statement, regarding the isolation of congested districts to contain nothing but fire-proof structures, the speaker most heartily concurs, not only because such practice would afford the "best insurance for buildings," but also because it would afford a maximum of safety and assurance for the whole community. With the statement, however, that "this is impossible in San Francisco, where business must be resumed with the least cost," or, indeed, that uniform fire-resisting construction is impossible in any city ready to take the lead; and also with the suggestion that "it would be good insurance for men owning large buildings to combine to buy out old and inflammable structures," etc., instead of throwing some such responsibility upon the city itself, the speaker begs to take most decided exception.

In the United States we are so prone to consider the rights of the individual that we are apt to overlook the rights of the aggregation of individuals. It is not denied that municipal building regulations adopted by any city, requiring uniform fire-resistive building construction after any fixed date, would give rise to seeming injustices and hardships, but if laws requiring the remodeling of present risks were also rigidly enforced, in addition to laws covering the erection of new buildings, the hardships would soon be equalized, and benefit accrue to the community in the way of reduced fire losses, reduced insurance premiums, reduced expenses for maintaining fire-fighting equipments, and added security to life and property interests.

"The fire problem, meanwhile, is with us, and it is not only for future buildings that we are concerned but with those that exist at present. Out of 300 000 buildings in the Metropolitan district (New York) not more than 2 000 are classed as thoroughly incombustible. With the remaining 298 000 we have got to deal. That these buildings can be made practically fire-proof—the word is used advisedly—is a statement which is not only capable of

demonstration, but has already been demonstrated by fire ex- Mr. Freitag.
perience.

"To safeguard these buildings is an engineering proposition pure and simple. The knowledge and ability are available and there is required simply a desire on the part of occupants and property owners. A very large percentage of the causes of fires is known, and can be eliminated from a building; there are on the market devices and systems of proved worth for detecting such fires as do occur, and for extinguishing them by automatic or manual means; a building can be planned to limit the area of fire; it can be prepared to facilitate the work of the public fire department; it can be prepared to reduce the loss resulting from fire and water and thereby reduce the fire tax. This outlined plan makes a standard for judging fire conditions, and if applied to any particular building, it would register in a definite and precise form the degree of consideration which the owner or occupant has given to the danger of fire."*

W. W. HARTS, M. AM. SOC. C. E. (by letter).—To those who Mr. Harts.
were present during the recent San Francisco earthquake, it requires no stretch of the imagination to believe that there might easily occur an earthquake of such intensity as to defy human skill to construct an edifice, anything like those now built, which would be able to withstand its power. The writer's experience in Manila in December, 1902, led him to think, at the time of the San Francisco earthquake, that the results in the city would not be very serious. That earthquake was not only longer in duration than the San Francisco shock, but was believed to be greater in the amplitude of the vibrations. The damage in the Philippines was slight, as buildings are purposely kept low, and are erected cheaply, with the earthquake hazard constantly in mind. Had it not been for the destructive fire in San Francisco, it seems safe to say that the earthquake and its results would have been only a nine days' wonder.

To what extent it seems necessary to provide for earthquake stresses in buildings, is a question of great nicety and careful judgment. It can scarcely be stated in pounds per square foot of superficial area, like wind pressure, which soon reaches a limit, although this method has been suggested. It partakes far more of the nature of insurance, so that, although there might be placed no limit to the expenditure for the protection of buildings from damage from this source, still an economical consideration will very quickly place a limit beyond which it is not desirable to provide against such risks.

The probability of the recurrence of dangerous shocks, and the estimate of the intensity can only be surmised. The additional expense, required in a structure for protection, therefore, would appear rather to be some percentage of the value of the building,

* *The Journal of Fire.*

Mr. Harts. if such protection were to be calculated upon a proper basis. That some protection for valuable buildings is advisable, is borne out by the admirable resisting powers of the Call Building. On the other hand, it is easily conceivable that small buildings might be built satisfactorily without any special reinforcement, should it be more desirable to run the risk of destruction than provide for protection. It is unquestionable that the class of buildings resisting the earthquake stresses most satisfactorily have been those in which a certain amount of elasticity was found, permitting the building to yield to the shock and return to its true position without injury. There appear to have been many cases where brick buildings, well constructed, complied with these conditions, and the many examples of brick buildings standing after both the earthquake and fire had done their worst, is a sufficient indication that the sweeping assertion cannot be made as to the "hopeless inadequacy" of this type of structure. It is very dangerous, in any scientific discussion, to formulate sweeping general rules, and, in view of the evidence, the statement of the Committee, with reference to brick buildings, should be more explicitly modified. Furthermore, the explanation has been made that the test of engineering structures is not experience, and that the majorities cannot be relied upon, as in town meetings, to discover the truth as to their stability. Can it be maintained that the science of engineering is not the resultant of years of experience? Can it be said that successes are not guides and that failures are not warnings? The fact that wooden composition bridges for railways yielded to steel arose through no fault of the composite type, but through other causes, such as the increase in weight of rolling stock, increase in cost of wood and its short life, but mainly through the decrease in the cost of steel. Such a change has unquestionably been based upon economical and not altogether on theoretical reasons.

One of the earthquake features which does not seem to have been mentioned is the rotary effect of the shock. Evidence of this came to the writer's notice in examining the different gas holders on the North Beach water front immediately after the earthquake. In all the cases examined these holders were twisted in the same direction —counter clock-wise. Each one of the holders was twisted about 2½ ft., breaking the rollers from the guides. Of course, the holder was useless until put back into its place and readjusted. The actual motion of the earth was very slight, but the effect on these structures was very curious and noteworthy.

Mr. Rix. E. A. Rix, M. Am. Soc. C. E. (by letter).—The writer has often thought that the geographical structure of the San Francisco Peninsula has something to do with the character of the vibration which results at different points. For example: The writer's residence is on the summit of Russian Hill, on the solid rock, where the strata

appear to be very much uptilted. The shock there seemed to be felt principally in a vertical direction, and the writer was not conscious of any great horizontal movement. The shock on the hill was severe, but in his rooms nothing was thrown from the walls. In one room there was a pedestal, about 4 ft. high, on which was a statue which had an insecure base, but this was not disturbed. The writer, therefore, has wondered whether the vibration was not reflected by the underlying stratum; or whether the severe horizontal movement, felt in the lower parts of the city, was not translated, or a portion of it, into vertical movement when it reached uptilted strata. Mr. Rix.

W. F. WHITAKER, JUN. AM. SOC. C. E. (by letter).—On the day of the earthquake the writer was running some levels in Bakersfield, Cal., and had great trouble with the bubble of his instrument. He knew that there had been an earthquake, but did not know that the quakes were continuing that afternoon. After the instrument had been nicely leveled, the bubble would move to one end of the tube. At first it was thought that the trouble was with the instrument, and another attempt was made to level it. After one or two trials of this kind it was discovered that if the instrument were left alone the bubble would move back to the center or perhaps to the other end of the tube. During the entire afternoon the same trouble occurred at intervals. The shocks were too slight to be felt. Mr. Whitaker.

The shock in the morning was felt by many, and caused some swinging of hanging objects. Although the writer was awake at the time, he did not know there had been an earthquake until told of it by others. In the evening, in discussing the peculiar action of the level bubble during the afternoon, the writer expressed the opinion that the shocks must be continuing, and learned later that this was true.

A. M. BIENENFELD, M. AM. SOC. C. E. (by letter).—A building under construction in Palo Alto, coming within the writer's notice, in which lime mortar was used, was badly wrecked, and it would seem that its destruction might be attributed to the use of the lime mortar. If all cement mortar, and no lime mortar, had been used, there would have been fewer wrecks of brick buildings. Mr. A. M. Bienenfeld.

The earthquake was not felt appreciably in Bakersfield, yet all the 70 or 80 steel tanks of the Standard Oil Company in that locality, which were filled with heavy viscous oil, were affected more or less. The tanks show that the oil spilled to the southwest, indicating that there was some tipping motion, or some motion of translation, sufficient to throw the oil in that direction. If there had been a return motion—oscillating, or vibratory—the oil would have spilled to the northeast, also, but the latter effect was not noted. It took about 2 hours for this phase of the earthquake shock to manifest itself at Bakersfield.

Mr. Adams. ARTHUR L. ADAMS, M. AM. SOC. C. E. (by letter).—It seems to be a question of definition and degree. What constitutes a severe earthquake, as the Committee uses that term, and of what degree of severity does it consider the earthquake of April 18th, 1906? Granting that earthquakes may be so severe as to wreck any class of structures, what degree of severity is to be provided for in the design of buildings?

It would seem that the Committee must define its position on these points in order to be fully understood.

Mr. Hindes. S. G. HINDES, M. AM. SOC. C. E. (by letter).—At the time of the earthquake the writer lived in an old house on Russian Hill, at the corner of Green and Leavenworth Streets. The house was built in 1860, and withstood the earthquakes of 1862 and 1868 without damage. The walls are entirely of concrete, 12 in. in thickness throughout their entire height, and rest directly on the solid rock. Four years ago, in making two large openings through the original walls, one laborer was able to cut a doorway in about two days, thus showing that the concrete had very little strength, there being probably very little cement used in it. Although the earthquake was not as severe on Russian Hill as in lower parts of the city, it was severe enough to unhook pictures and throw them across the room, but these walls were practically uninjured. The inside plaster was somewhat cracked, but the walls themselves are apparently unhurt. There is no reinforcement whatever in the walls.

Mr. Hunt LOREN E. HUNT, ASSOC. M. AM. SOC. C. E. (by letter).—The writer desires to call attention to a few notable examples of brick construction which successfully withstood the earthquake shocks about a year ago. All San Francisco engineers are familiar with the buildings and will agree that they represent good brick construction. They are the older Federal buildings in San Francisco. The "Appraisers Building" suffered practically no damage. The "Mint" was less damaged than the modern steel Post Office two blocks away. Most remarkable, however, is the case of the old Government building now known as the "Sailors Home," which was condemned as "unsafe" thirty years ago, and yet came through the disaster practically unharmed. It is not affirmed that good construction is the only reason that these brick buildings are still standing, but good construction was certainly an important factor. Their preservation is a tribute to the care and efficiency of the Government engineers.

Mr. Duryea. EDWIN DURYEA, JR., M. AM. SOC. C. E. (by letter).—The concrete pumping-pit of the Palo Alto municipal water-works, about 50 ft. deep, was at first thought to be undamaged by the earthquake, as no cracks were visible in the walls. Later, however, it was found that where the well-casing entered the base of the pit, the joint had been broken by the earthquake so that whenever the pump (a centrifugal

pump placed on the bottom of the pit) was stopped, the pit rapidly filled with water nearly to the ground surface. Largely on account of the crowded condition of the pit and the interference of the work at the base of the pump, etc., the expenditure for repairs was about $1 300. Mr. Duryea.

BERNARD BIENENFELD, M. AM. SOC. C. E. (by letter).—In the earthquake countries of the Far East, it is the practice, as elsewhere, when putting up substantial buildings, to go down to solid material, preferably rock, for foundations. The overlying loose material, or earth, is thereafter cut away and kept clear from contact with the foundation walls. It is the excessive motion and jelly-like tremors in the loose earth that cause the greatest damage in an earthquake shock. By thus avoiding contact between the comparatively incoherent superficial earth and the walls of the building, the vibration is minimized. It would be well to follow this practice in San Francisco. This might necessitate the use of curb or slight retaining walls to confine the loose earth, and such walls, both in their footings and on their faces, should be separated from the main building walls. Such a construction would add somewhat to the expense of construction; but the additional first cost would be a very cheap and efficient insurance against future disaster. Mr. B. Bienenfeld.

Regarding the contention of the Committee that the ordinary brick construction is inelastic, observation of the action of the brick walls of wrecked buildings that were being torn down subsequent to the earthquake and fire would indicate that there is indeed a considerable and surprising internal elasticity in this form of construction. Wherever good work had been done, and where the foundation was firm, brick buildings passed the ordeal of the shock remarkably well.

It is undoubtedly true that a proper reinforced-concrete construction on a proper foundation is among the forms best calculated to resist earthquake shocks; but it is none the less evident that a properly founded and constructed brick building has earthquake-resisting features considerably greater than the Committee has indicated.

It is to be deeply regretted, however, that the class of brickwork now being done in the rehabilitation of the city is generally of a nature to invite serious disaster in future severe earthquakes. The throttling restrictions of the labor unions, and the indifference and incompetence of the municipal building authorities are particularly blameworthy.

J. P. CARLIN, ASSOC. M. AM. SOC. C. E. (by letter).—Concerning the reviews and discussions of the conclusions reached by the Committees of the San Francisco Association, the writer is glad to note the unanimity of opinion, regarding the criticism of the Mr. Carlin.

Mr Carlin. Committees' finding, with special reference to brick construction on the San Francisco Peninsula. The following conclusion was reached by the Committee:

"It may be stated, as one of the most obvious lessons of the earthquake, that brick walls, or walls of brick faced with stone, when without an interior frame of steel, are hopelessly inadequate."

This was not at all obvious to the writer, when he examined the ruins, and, he believes, is not the fact.

In determining the damage to any of the wrecked buildings, careful investigation was required in order to ascertain what proportion was due to the fire and what to the earthquake. The civic pride of the people of the ill-fated city prompted them to attribute nearly all the destruction to the fire, and consequently their opinion must be discounted for bias. On the other hand, it would seem that many visiting committees have reported upon the ultimate damage as they found it, and have failed to consider properly the earthquake damage independently of the fire.

The vigilance committee in San Francisco, or "Committee of Safety," organized immediately after the fire, used heroic measures in leveling the ruins; and, naturally, the buildings to suffer most were those since brought under the ban of the beforementioned Committee. Dynamite was used unsparingly, especially in razing unsupported brick walls, wherein fires had completely gutted the interior because they were not of steel frame or so-called fire-proof construction. Consequently, there are, or were, but few cases in which buildings of brick exterior walls were left standing; but, such as did remain are classic examples of slow-burning construction in championing the cause of brick buildings in San Francisco when properly built.

The writer made a personal examination and report on the ruins of the Palace Hotel, and with special reference to reconstructing it without razing the existing walls. This structure covered an entire block, in area about 250 by 300 ft., was seven stories high, and was of brick throughout. Along the Market and New Montgomery Street façades, there were iron columns with supporting girders for sprandrel-wall construction up to the second-floor level, and there were interior steel girders supported on brick walls; but, in no sense was the building a steel-frame interior, for the interior walls throughout were of common brick.

This building—the largest brick hotel in the world—was almost uninjured by the earthquake, excepting for a few minor cracks, but was, of course, completely gutted subsequently by the fire. An examination of the ruins showed that the brick walls were in excellent shape—straight as to alignment, and without other fracture than was obviously caused by the fire—and the construction was

unimpaired at all the salient points of the building. The bonding, at the corners and at the points where the interior walls intersected each other or the main walls, was perfect; and this fact is mentioned especially because, in all steel-frame structures, with brick exteriors, the bonding of the front wall to the side walls was almost invariably cracked. Mr. Carlin.

Many of the steel-skeleton buildings were branded by Nature's condemnation marks, in the shape of *X*-cracks, about midway of the height. These were due to the flexibility of the structure, thus permitting the foundations to move coincidently with the shock and before the superstructure; and, being followed by the latter, in an effort to regain equilibrium, produced great stresses about the middle third.

The Foljer Building, on Howard Street, was of brick exterior and wood interior, and was left standing after the earthquake, the fire not having reached it. As was generally the case in buildings of any description, the chimneys suffered and a small portion of the parapet wall, but otherwise the building was not damaged; and yet, at this very site, the street in front of the building had settled about 2 ft. The California Electrical Works Building, on Folsom Street, was of similar construction, and, barring the usual roof disturbance, no damage was done by the shock.

The foregoing is positively and negatively in favor of ordinary brick buildings. It seems to the writer that a most important point with reference to building construction in earthquake countries has not been emphasized sufficiently, or has failed utterly of consideration, and that is to treat the subject as a problem akin to one of buoyancy in water, and, in the design of building construction, to apply the principles of flotation. A familiar example of lack of stability in marine architecture is, of course, a small craft of little draft or beam in a heavy sea. To obtain rigidity, the displacement of a craft is increased, and, for this purpose, lead is added to her keel. Now, the undulating action of an earthquake is not unlike ordinary wave action, and should be treated in the same way. If, therefore, the foundations are designed so as to be sufficiently heavy, and are made a unit, with reference to the superstructure, the building will either safely ride the earthquake wave, or, if the superstructure is not of flexible construction, it will move with the foundations, just as a ship does, and as a unit.

The Post Office Building well illustrates the necessity for unified foundations. This building was on piles, and was located in the Mission District, which is to a great extent "made land." Although the structure was of heavy construction, it was practically supported on stilts, and the earthquake wave motion moved through this forest foundation, following and developing lines of

Mr. Carlin. least resistance, with consequent promiscuous racking all over the building. At the four corners the cracks were most pronounced, exactly at the angle where the heavier portions of the building joined the lighter contiguous connections. These four flanking corners were on unit pile foundations, as regards themselves, and moved independently with reference to the remainder of the building. Had this entire building been piled uniformly, and—more important still—had the foundation been capped with a solid layer of concrete over the entire site, and of sufficient thickness and depth to make the resulting mass a unit, it is believed that the structure would have withstood the shock, and would have ridden safely the petrified waves, which now appear so clearly in the immediate vicinity of this building.

In recent years, it was necessary to design a special method of foundations to meet the soil conditions in Chicago. This consisted of steel grillage embedded in concrete, and was called the "Chicago method," or "floating foundation." This, of course, has been superseded by caissons carried to rock.

It seems to the writer that San Francisco, in its reconstruction, will be forced to accept the "floating method" of foundation where it cannot reach bed-rock economically with a unified foundation, and that it should also use a rigid type of superstructure. Obviously, this will be obtained best by heavy masonry construction, like that of which the Palace Hotel structure was a type. These suggestions are not advanced on the score of either economy of space or of construction, but they seem to be best adapted as methods of building construction in regions of seismic disturbance.

Mr. Goad. CHARLES E. GOAD, M. AM. SOC. C. E. (by letter).—Conflagrations seem to be prevalent chiefly in that portion of the North American Continent inhabited by the Anglo-Saxon race, mainly owing to the "inordinate greed of immediate gain" that characterizes the construction of rapidly growing centers of population.

There are from 5 000 to 6 000 cities, towns and villages, in the United States and Canada, in continual danger of being swept by fire; thus it would seem reasonable that the question of the "Best Means for the Prevention of Conflagrations" should have serious consideration by all persons interested in the welfare of the community.

This subject is worthy of the attention of the American Society of Civil Engineers. Statistics, easily obtainable, show that the fire wastes by conflagrations (besides those caused by ordinary isolated fires) are appalling. More than 1 000 000 buildings in 10 years, says one authority; in 39 years (1866 to 1904) more than $542 000 000 of fire waste in conflagrations alone.

How often have we, who know these dangers, walked through the

congested districts of our principal cities and towns, wondering why they still existed; and, on seeing "fire-traps" and "sources of danger" being hurriedly run up, do we not frequently wish for a dictator's power to stop such rash and foolish construction? Mr. Goad.

The natural foes to be met by civil engineers are taken to be water and decay. Fire, usually considered as a servant, should be regarded with more attention as a possible enemy. After a serious conflagration, there always ensues a period of "proposed amendments and improvements," all too soon forgotten when the temporary panic has ceased.

The chief "physical" preventions to the spread of conflagration may be summarized as:

1.—Impervious walls and fire-resisting construction;
2.—Wide, and open spaces;
3.—Abundance of water, concentrated at the proper place, at the right moment.

The chief "moral" preventive is:

To have officials (more than one) with knowledge of how to act, and with authority sufficient to obtain immediate organized help.

Impervious Walls.—Much can be done by insisting that, in certain districts well known as liable to conflagration hazard, some walls should be constructed so as to prove a barrier to a fire that has become temporarily beyond control.

There is one good wall in the heart of London City that has already to its credit the stay of conflagrations in five instances, and the members of the fire brigade hail with delight the aid of their "old friend," when a fierce fire meets it again.

The London County Council is gradually introducing by-laws making improvements in this direction, and there is a tendency among municipal authorities to consider these matters on a more comprehensive scale.

Not only vertical, but also horizontal, fire-breaks are worthy of attention. Since the Cripplegate fire (London, November, 1897), building acts have been amended so that every alternate floor in that district must now be fire-resisting.

In the old City of Stamboul, the Turkish part of Constantinople, two stone walls, 40 ft. high, have been erected in the "Lumber District," and more are needed.

The European suburb, across the Bosphorus, Kadi-Keui, consisting mainly of buildings of wooden construction, appears to have laws which compel the construction of a brick wall, without openings, on one side of a wooden building. While it looks curious, and somewhat absurd to a chance visitor, to see a dead brick wall

Mr. Goad. on one side of a wooden building, with nothing but vacant fields for 500 ft. distant, yet had such a law been enforced in communities of wooden structures on this Continent, before buildings became grouped in closely congested areas, the aid to the prevention of conflagrations would be obvious.

Wide, Open Spaces.—After every conflagration, efforts are made to increase the width of streets, and to open wide, new thoroughfares, but, as a rule, "vested interests" prove too apathetic, and nothing is accomplished.

After the Great Fire of London (September, 1666) Sir Christopher Wren urged the construction of wide thoroughfares, and prepared a plan, the adoption of which would have been of immense benefit; but he was too far in advance of his age, and his plans were not carried out.

St. John's and Carbonear, Newfoundland, are instances where "fire-breaks" of great width, but of too limited an extent, were adopted after serious fires.

Our forefathers in New England and in the Maritime Provinces usually managed to allow sufficient space between wooden buildings in order to prevent conflagrations; but now-a-days the greed for immediate gain is such that fire-traps are allowed to be run up in close proximity to each other, and the danger is overlooked, or, if considered, is merely inadequately guarded against by fire insurance.

It would be well within the powers of hundreds of towns and villages that are springing up all over the country, to forbid the erection of wooden buildings within 50 ft. of one another, until such time as proper fire-resisting walls were built to intervene between them. The same rule should apply to suburbs of cities consisting of wooden buildings, wide thoroughfares being made wherever practicable, the widening of all principal streets being encouraged, even if at an apparently extraordinary expense.

Dynamiting Buildings.—This method is considered to be poor policy in staying a conflagration, as the shattered, disintegrated mass is the more easily ignited, and windows, hundreds of yards away, are blown in, affording ready access to burning embers.

Abundance of Water.—A lesson to be learned from the record of nearly every conflagration is, that the control of the water supply should be such that, in time of need, certain sections could be supplemented by an increased volume of water, and that it should be practicable to cut off each section in which the firemen have been driven from the hydrants without having had time to close them.

The old-fashioned system of underground water cisterns had many advantages, though, where water-works have been installed, these cisterns have generally been abandoned as unnecessary. In

the case of failure of water systems through earthquake, accident, or malicious interference, however, the supply from cisterns would be an important factor in the fight against a sweeping conflagration. Mr. Goad.

Ponds, or small artificial lakes, in central squares, while beautifying the city or town, would also serve a useful purpose in times of conflagration. A small quantity of water judiciously used can be made to accomplish great results; this is known from actual experience.

The "Moral Preventive."—The moral preventive is to prepare for war in times of peace—to have men trained to meet a disaster —not merely one chief, who (as in many instances of late) may be incapacitated by accident, or who may be absent, but several. These men should be trained to work together, and should have a thorough knowledge of the water systems and of possible fire-breaks; they should be always in readiness to take action at the time, instead of, as is now too often the case, each one acting in such a manner as to retard the efforts of the others by want of knowledge and lack of previous instructions.

The managers of fire insurance companies frequently do good work in preventing conflagrations, though they are usually roundly abused for increasing the rates; they would deserve commendation if they not only would raise the rates, but would also make them prohibitive, or if they would decline to insure in districts which seem designed to foster the spread of conflagrations. This is now actually done by some managers, yet the majority will still accept such risks, and assist in the continuance of careless and "tinder-box" construction.

The British Fire Prevention Committee, founded in 1897, composed of architects, civil engineers, district surveyors, etc., in Great Britain, is doing valuable work in inculcating better methods of construction, with special reference to resistance to the spread of fire; its reports (now numbering 120) of fire tests, and of matters pertaining to this subject, will be of interest and service to students of fire resistance.

The National Fire Protection Association, including fifty "underwriters' organizations and engineering bodies," is doing good work on similar lines on this Continent.

The reports of the Committee of Twenty of the National Board of Fire Underwriters are valuable documents, serving to show where danger exists, and how to combat it.

While it must be acknowledged that no drastic methods of reconstruction of "congested-centers" will be tolerated by a community at the present time, yet there is hope that, by calling especial attention to impending dangers, and, by submitting remedies

Mr. Goad. at every favorable opportunity, much can be done to educate the people in the science of safeguarding their homes against destruction by conflagration.

Mr. Green. R. B. GREEN, M. AM. SOC. C. E. (by letter).—The failure of the water supply for fire protection having led to a fire loss which far exceeded that from shock, it is interesting to note the respective reports of the three Committees on Water-Works, Lighting and Street Railway Transportation, and Sewers.

The first states that pipe lines and conduits, of any character whatever, are almost certain to fail when intersected by a plane of large movement; the second, that "The underground conduit system and the Edison tubing came through both earthquake and fire in very good shape;" and the third, that sewers on rocky ground were uninjured, while those on made land were wrecked, but all the wrecked sewers were old brick ones, the joints of which were of sand in place of mortar; and recommends reinforced concrete sewers. In the search for all possible emergency aids, it would seem that deep trunk sewers might furnish a supply of water for a fire-engine's suction when all regular water supplies are crippled. Every manhole would be a possible suction well.

A shock that would cripple a water main under pressure might break a trunk sewer, but would probably not choke it so as to prevent ground-water from coming down and back-water from backing up from the outlet, unless there should be a tidal wave, such as would cripple even a fire-boat service. Back-water often extends in trunk sewers up through the low-level business sections of water-front cities, and could be had in new sewers by dropping a small portion of the invert below outlet level. A brick intake main extending back through the lower parts of a town would be similar, but more costly. Similarly, sewers in higher districts, known to have large inflows of ground-water, might also furnish a certain amount of aid in extreme emergencies. Bags of sand, to dam a small flow, or drop-sumps would aid in the smaller sewers.

Gates or temporary dams at the outlets of large sewers would aid in backing their flow up to the higher levels distant from the harbor front. This effect would be aided by having the fire-boats pump into the sewers after their outlets were closed.

Another aid would be obtained by having special fire protection piping in suitable piping subways. This piping, if loosely hung or laid through the subways, might pass through a shock that would cripple a pipe rigidly buried; or, if broken, would be immediately accessible in the subway and could be repaired quickly by special sleeves. This piping could be connected to the fire-boats or to special auxiliary pumping stations near the water edge.

C. E. MOORE, M. AM. SOC. C. E. (by letter).—The writer has been deeply interested in earthquake strains for several years, and, in the design of structures, he has endeavored, as far as possible, to provide for such strains. Some years ago the matter was taken up and reference was made to such reports as were available, these being mainly derived from experience in Japan. In general, it has been assumed that the strains were caused by lateral motion only, and that the vertical component was too small to be taken into account. As a rule, this is no doubt true, and the general correctness of the report of the Committee regarding the absence of vertical movement in the earthquake of April 18th is not questioned. However, from observations made by the writer, it seems to be clear that there must have been some vertical movement within a limited area in the Santa Clara Valley. As far as observed by him, the district in which this movement seems to be indicated is not more than 1 mile wide and 10 miles long. In that area there were some instances which appeared to indicate an upward impulse of a very decided nature. Mr. Moore.

Out of many cases, four have been selected as typical, and are included here:

First.—One of these is the manner of failure of the water tower at Santa Clara, which is described in the Report of the Committee on Water-Works Structures. It may be repeated here that two tanks were thrown off, and the remaining two were moved fully 20 ft. on the floor of the tower before falling. There can be no doubt of this, as it was seen by several witnesses, and it is indicated by the subsequent position of the tanks and columns. It is hardly conceivable, to one who is familiar with the situation, that this movement could have been caused entirely by sliding.

Second.—At Mountain View, at the other extremity of the area above alluded to, a timber structure was destroyed in a manner apparently similar. At Palo Alto, a few miles farther to the northwest, a structure of exactly similar construction, and about 25 ft. higher, was uninjured.

Third.—At the Santa Clara College, a large weather vane on one of the buildings has a shaft about 4 in. square. This stood in a cast-iron socket 12 in. deep, making a fairly close fit. This shaft was thrown out of the socket, neither being broken.

Fourth.—At the Catholic Cemetery at Santa Clara, a monument about 8 ft. high, the large end being 12 in. square, rested upon a base 4 ft. high. It was secured to the base by a brass pin $\frac{5}{8}$ in. in diameter. The monument proper was thrown off the base, turned completely over, and laid with the top end next to the base and the large end (or bottom) away from it. The brass pin stood vertically 7 in. above the base, and was not bent. At the Protestant Cem-

Mr. Moore. etery, half a mile farther west, no such effects were produced, although several monuments were thrown down. At the County Hospital, a mile to the south, and on somewhat higher ground, the buildings were practically destroyed, but a steel structure carrying water tanks, which was erected by the writer several years ago, was uninjured. A large quantity of water was thrown out, as the tanks were nearly full, but they did not move from the floor. In their construction, there was no reason for this which did not exist also at Santa Clara and Mountain View.

At Agnews' Insane Asylum, 2½ miles north of Santa Clara, and on lower ground, near the marshes of San Francisco Bay, there was, as stated in the Report of the Committee on Water-Works Structures, a structure similar to that at Santa Clara, which was uninjured. The tanks were empty at the time, so that probably no valuable conclusion can be drawn from this fact. However, the Committee on Fire and Earthquake Damage to Buildings reports no evidence of vertical movement there, and this was the conclusion reached independently by the writer.

The axis of the strip above referred to follows along the edge of the "Artesian belt," or "Lowlands," as it is known in the Santa Clara Valley. This line passes near the Mountain View Water-Works, the Santa Clara Water-Works, through College Park, and near the Hotel Vendôme, in the northern part of San José. By following this line and going not more than half a mile on either side, one could easily locate fifty badly wrecked frame buildings. At College Park there were many, all being near this line. West of the Alameda (about half a mile from the line indicated), there was not a single case of this kind. The writer is of the opinion that the Committee's statement, that "damage to buildings * * * was confined to those faulty either in design or in construction," should be modified, as regards this locality. These buildings could not be classed as "faulty." All through the country an occasional defective building was wrecked, but in this locality the list included many good buildings, and it is these to which reference is made.

The Hotel Vendôme (a well-built frame structure) was wrecked so badly that it has been practically rebuilt, and has only recently been opened. Many residences in that vicinity fared similarly, although, half a mile farther south, such buildings suffered comparatively little. From all this it seems that the effect varied greatly in different localities, and it is not safe to conclude that, because no evidence of vertical movement is found in certain buildings examined, such movement did not occur at other points. The variation with locality appears to have been recognized in countries where earthquakes have been frequent, as one writer says: "Certain

areas in earthquake localities have been marked off as unsuitable for any buildings." Mr. Moore.

It has seemed to the writer that the formation of the ground in these localities may explain, at least partly, this variation.

It would appear that any mathematical investigation of the waves would be impracticable and useless, on account of the great diversity in the character of the material passed through.

It appears, however, that the oscillations are transmitted from the seat of the disturbance by a wave movement, which must involve vertical motion, although possibly such motion may be very small. It appears also that this primary wave has a very long wave length, which renders the vertical component imperceptible. At Mount Hamilton (Lick Observatory), 20 miles to the east of Santa Clara, and at the summit of a rocky range, there was reported "no vertical movement."

At a small observatory at College Park, instruments were dismounted and no record was made. It seems, however, that, in certain localities, secondary waves are generated, and, as to magnitude and form, these depend upon the character of the ground traversed. At the Santa Clara Water-Works, there is, under a few feet of soil, a stratum of stiff yellow clay, underlaid by a stratum composed of sand and water, approaching quicksand in character. Rock is at an unknown depth, certainly as great as 1 200 ft. To the west, on higher ground, the clay stratum becomes deeper, being covered by from 30 to 50 ft. of mixed clay and gravel. The lower stratum is quite different in character, or is entirely absent.

At Agnews', the clay stratum is either absent or is covered by many feet of adobe. It appears, then, that the area referred to in the beginning is limited to a locality where a stiff clay is underlaid by a yielding stratum; and that secondary waves pertain chiefly to the surface, and do not affect the ground to any great depth.

It seems to the writer that a movement somewhat similar to that observed here may have occurred in other localities where the damage was greatest, for instance at Santa Rosa.

At Santa Clara, the first waves were from the southwest, but, before these ceased, they were crossed by waves from the northwest, these, as stated by Dr. Jordan, of Stanford University, being due to oscillations from more distant points along the fault line. The crossing of waves caused a twisting movement, by which many buildings were turned on their foundations, so that the two ends projected in opposite directions from the foundations to the extent of 2 or 3 in. This occurred with many frame houses, and in the case of certain large buildings in San José.

Referring to permanent vertical displacement, as distinguished from the vertical wave component, Dr. Jordan states that along

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the fault line, at the summit of Black Mountain, there was a relative change of level amounting to 2 ft., indicating at that portion of the line either a rising of one side or a subsidence of the other. The presumption is, however, that this effect does not exist, to any appreciable extent, for any great distance from the fault line.

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A. L. A. HIMMELWRIGHT, M. AM. SOC. C. E. (by letter).—The Report of the Committee on Fire and Earthquake Damage to Buildings was eagerly awaited by all who have to do with the construction of modern buildings.

The span of human life is short, and a disaster such as that which occurred in San Francisco will probably not be repeated in another century. The lessons which it taught, and especially the effect on fire-proof buildings, are of such vast importance that a critical, careful, and detailed investigation and report would have been a valuable contribution to our knowledge of building construction. It is to be regretted that all the photographs taken and collected by the Committee could not have been printed with the report, because such illustrations are frequently more satisfactory than verbal descriptions. It is also unfortunate that the Committee's report is so brief that, in many cases, it is necessary to indulge in general statements, which are entirely too broad, and to that extent are misleading. A detailed report which would have embraced twenty times the space taken by the Committee would have been welcomed gladly by the architectural and engineering professions.

In the design and construction of buildings of the better class, which are now made as nearly fire-proof as possible, architects and engineers are searching constantly for those materials and methods which will show the best efficiency and fulfill the purpose for which they are intended. Definite and exact information on this subject is what is desired particularly. The behavior of any given material under varying conditions, or of the same material used in different ways, would supply information of the kind sought. The fact that all materials are damaged more or less when exposed to intense heat does not interest the designer; but the fact that one material proved more efficient than another, under the same conditions, is valuable information. Instead of collecting information of this character, the Committee seems to have made an effort to generalize and classify results, which practically nullifies the usefulness of the report.

There are in the report a few statements of facts which are somewhat at variance with the writer's observations. On page 322* a statement is made that the Bush Street front of the Mills Building leaned toward the street from 7 to 9 in. Careful determination,

* *Proceedings*, Am. Soc. C. E., for March, 1907.

made under the writer's direction, in the latter part of May, 1906, showed that this front leaned out toward the street only from 4 to 5 in. Mr. Himmelwright.

The very severe condemnation of masonry-walled structures without steel frames is a little unwarranted. Where the walls were tied together and the masonwork was executed with good Portland cement mortar, neither the earthquake nor the fire caused any serious damage. The Palace Hotel and the Parrott Estate Building, at the northwest corner of California and Montgomery Streets, are two noteworthy examples of brick and stone masonry without interior steel frames which stood the test with very little structural damage.

The writer takes decided issue with the Committee on the general statement, on page 329,* that "all materials were destroyed when directly exposed to the fire for any length of time." While it is admitted, by those thoroughly informed on this subject, that the different building materials have varying relative values, from a fire-resisting standpoint, it is now an established fact that there are materials capable of resisting in a thoroughly satisfactory manner, and with inappreciable damage to the material itself, any exposures to flames and heat which are likely to occur in any large conflagration. This is an important fact which should have been defined clearly in the report.

In considering the subject of the material for fire-proof floors, only two kinds are mentioned, namely, terra cotta and concrete, and the statement is correctly made that, of these two materials, "terra cotta suffered the more"; also that, "in all cases the record of concrete is better than that of tile." No distinction, however, is made between different kinds of concrete and tile and different forms in which they were used. There is a vast difference in the fire-resisting qualities of concretes made from different aggregates, and in the case of the same aggregates used in different ways. There is also a difference in the fire-resisting qualities of hollow-tile blocks.

The writer has made an extended study of the fire-resisting qualities of different materials used for fire-proofing purposes, not only in San Francisco and Baltimore, but also by full-sized, practical fire and water tests which have been made at different times under his direction. It is well known that stone concrete, whether the aggregates be of granite, sandstone, limestone, or trap rock, suffers from dehydration when exposed to heat, and for that reason is less desirable as a fire-proofing material than concrete made from aggregates which do not contain "water of crystallization." It has been demonstrated that stone concrete, when exposed to a temperature of from 1 800 to 2 000° fahr., for a period of 4 hours, will be affected

* *Proceedings*, Am. Soc. C. E., for March, 1907.

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by dehydration to a depth of from 3 to 4 in., and the strength of the concrete will be seriously impaired to that depth. When the concrete has been damaged by dehydration, the aggregates break and disintegrate, and the bond between the aggregates and the cementing material is lost, so that an ordinary fire-stream, under 60 lb. pressure, will easily abrade the under surface, and wash it away. If the concrete is allowed to cool after being heated, and without the application of water, the dehydrated surfaces can be picked apart by the fingers, or easily removed with a small tack hammer, to the depth to which dehydration has taken place. All natural rock contains moisture, and for that reason concrete made from any variety of stone aggregates will be dehydrated when subjected to heat, and consequently is unsuited and poorly adapted for use as a fire-proofing material in any position where it is likely to be subjected to high temperatures.

The fundamental principle in a concrete for fire-proofing purposes is the use of aggregates which do not contain moisture, but which, when made into concrete, possess sufficient strength to fulfill the requirements. Steam-boiler cinders, crushed furnace slag, crushed brick, and "tetzlonti" (a light, porous, lava rock occurring in the vicinity of the City of Mexico) are the materials best suited for fire-resisting concretes which have been found to be commercially available. Concrete made from these materials, with very little ramming, to secure lightness and porosity, has been shown to possess excellent and satisfactory fire-resisting qualities.

Another important feature of a concrete which is to resist heat is the presence of voids. A "full concrete" in which the voids are filled solidly with cementing material is desirable from the standpoint of strength, but this feature detracts very largely from its fire-resisting qualities. The ordinary requirements for strength in building construction, where these materials are used for fire-proofing purposes, are amply fulfilled by a concrete which possesses a large percentage of voids, so that their presence is a decided advantage in ordinary fire-proof floor construction.

The different forms and the principles involved in the construction of concrete floors have also an important bearing on the efficiency and fire-resisting qualities of the different methods. In all recent large conflagrations, the segmental arch, in which all the material is used in compression, and in which the strength is independent of light metal elements, proved to be in a class by itself, and developed fire-resisting qualities and strength vastly superior to any of the flat-slab methods in which light steel reinforcing elements were used in tension.

In all the flat-slab methods in which steel tensile elements are used the economical position of the reinforcing metal is invariably near

the under surface of the slab, and as far away as possible from the neutral axis. When located in this position, the nearer it is to the under surface of the slab, the more it is exposed to the effect of the heat when attacked by fire; and, when thus exposed, the reinforcing metal has very little value as a load-sustaining portion of the construction. Mr. Himmelwright.

When the reinforcing metal is covered with 1 in. of stone concrete, which is the maximum thickness of covering usually provided, experiments show that the metal is heated to a temperature of about 800° fahr. in about 1 hour, and to 1 300° in from 3 to 4 hours, when subjected to a uniform temperature of 1 800° fahr. At 800° fahr. reinforcing steel loses approximately 26% of its strength, and at 1 300° its strength is practically nil.

The flat-slab methods in which steel is used in tension are, for the above reasons, vastly inferior, for horizontal-load sustaining construction, to the segmental arch methods. In wall and partition work the use of metal reinforcement near the center of the section is much less objectionable, as the metal elements act largely as stiffening and bracing members, and the slab, being in a vertical plane, sustains its own weight and is therefore less likely to be deflected and damaged when subjected to heat.

The most elaborate and instructive fire and water tests ever made were conducted by the New York Building Department in 1896 and 1897, under the direction of Mr. Gus. C. Henning. These tests were made scientifically, and are on record in the Department. A brief *résumé* of three of these tests will be interesting in connection with this discussion. On December 23d, 1896, a stone-concrete, flat-slab, floor section, 11 by 15 ft., was tested by fire and water. The concrete floor was supported by two steel beams at about 4-ft. centers. The reinforcing metal consisted of bars at 16-in. centers, the under side of the bar being about $\frac{5}{8}$ in. from the under surface of the concrete floor slab; the section of the bar was $\frac{1}{4}$ in. by 2 in., the 2-in. dimension being vertical. The concrete was mixed in the proportion of 1 bbl. of Dyckerhoff Portland cement, $2\frac{1}{2}$ bbl. of sand and 5 bbl. of small broken blue stone passing a sieve of 1-in. mesh, with 12.8% of water in bulk. Rock wall plaster, mixed in the proportions prescribed by the manufacturers, was then applied to the under side of the flooring to a depth of about $\frac{3}{8}$ in. A second coat of this plaster was applied later, making the total thickness of the plaster from $\frac{1}{2}$ to $\frac{5}{8}$ in. A white finish was then applied in the usual manner, representing the usual conditions in finished buildings. This floor formed the roof of the test structure built for the purpose, and was located about 10 ft. above a grate, of the same area as the floor, on which a hardwood fire was maintained to produce the temperatures. The fire was started at 10.30 A. M.,

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and the following temperatures (as recorded by a Uhling and Steinbart pyrometer) were produced at the times set opposite:

Time.	Temperature, in degrees, Fahrenheit.	Time.	Temperature, in degrees, Fahrenheit.
11.13 A. M.	1 775	2.00 P. M.	1 950
11.30 "	1 850	2.40 "	2 100
12.00 M.	2 050	3.00 "	2 200
12.30 P. M.	2 000	3.30 "	2 100
1.12 P. M.	2 100		

At 3.30 P. M., while the ceiling was observed to be in a red-hot condition, water, at a pressure of 60 lb., was applied to it with a fire-hose having a regular 1⅛-in. nozzle. Some of the plaster had fallen away previously, and the remainder was washed away by the water. The fire-stream also abraded the entire under surface of the stone concrete flooring to a depth of 1¾ in., wherever the water struck it, exposing all the reinforcing bars to an average of about one-half their depth.

The abrasion of the concrete to the depth stated was due, no doubt, primarily, to dehydration of the stone, and secondly to rupture and disintegration caused by the sudden cooling while highly heated, on the application of the fire-stream.

A similar fire and water test was made on a flat-slab, cinder-concrete floor on April 23d, 1907. The concrete consisted of 1 bbl. of Atlas Portland cement, 2 bbl. of clean, sharp sand, and 4 bbl. of steam-boiler cinders. The reinforcement consisted of 2½ by 6-in. mesh expanded metal of No. 10 gauge. This was laid directly on the centering, and the concrete was deposited over it to a depth of 4 in. The plaster was King's Windsor cement, applied in accordance with the manufacturers' specifications, in two coats, to a total thicknes of about ½ in., approximating to the same condition as in the test previously mentioned. The fire test was started at 10.05 A. M., and at the following times the corresponding temperatures were obtained:

Time.	Temperature, in degrees, Fahrenheit.	Time.	Temperature, in degrees, Fahrenheit.
10.52 A. M.	1 800	1.12 P. M.	2 000
11.30 "	2 200	1.40 "	2 100
11.58 "	1 900	2.30 "	2 050
12.06 P. M.	2 100		

At 3.05 P. M., water, at a pressure of 60 lb., was applied to the ceiling with a fire-hose having a regular 1⅛-in. nozzle, while the under side of the flooring was observed to be in a red-hot condition. Wherever the water struck the ceiling the plaster was washed off,

but only a very small quantity of the cinder concrete was abraded, barely enough to loosen in spots the expanded metal fabric, the under side of which was flush with the bottom of the slab. Mr. Himmelwright.

A similar test was made of a segmental, cinder-concrete arch on October 28th, 1906. The concrete was mixed in the proportions of 1 part Aalborg (Danish) Portland cement, 2 parts clean, sharp sand, 5 parts steam-boiler cinders, without screening or washing, and as taken from the chutes of the New York Steam Company, and 1.35 parts water. This concrete was laid on a permanent wire centering consisting of No. 19, four-warp, two filling wire-cloth, stiffened by $\frac{7}{16}$-in. round steel rods woven in at intervals of 9 in., segmental in form, providing for a thickness of about $3\frac{1}{2}$ in. at the crown of the arch, the concrete being placed in position without ramming and by simply patting and smoothing the top surface with shovels. The plastering consisted of ordinary lime mortar furnished by the United States Mortar Supply Company, of New York City, and the two coats aggregated $\frac{5}{8}$ in. in thickness. One entire bay, or one-third of the under side of the floor area, was left unplastered so as to expose the concrete to the direct action of the flames. The fire test was started at 10.06 A. M., and the following temperatures were obtained at the times set opposite:

Time.	Temperature, in degrees, Fahrenheit.	Time.	Temperature, in degrees, Fahrenheit.
11.14 A. M.	1 700	1.06 P. M.	2 100
11.35 "	1 900	1.45 "	2 050
11.55 "	2 050	1.57 "	2 125
12.16 P. M.	2 000	2.18 "	2 130
12.30 "	2 150	2.55 "	1 950
12.43 "	2 300		

At 3.06 P. M., water, at a pressure of 60 lb., was applied to the ceiling with a fire-hose having a $1\frac{1}{8}$-in. nozzle, while the under side of the flooring was observed to be in a red-hot condition. The following is quoted from records of the Building Department:

"Close examination of the concrete showed that the wire netting had been completely burned off in the naked arch. The concrete arch (unplastered) seemed not affected in any way by the fire or water except small spots washed away where water struck with great force."

The spots referred to were not more than $\frac{1}{4}$ in. in depth, and did not aggregate more than 3 sq. ft. of the entire surface.

Several months after this test was made, two 2-in. cubes, made from the concrete which had passed through this test, were tested for strength, and developed a crushing strength of 940 lb. per sq. in., which shows about the same strength as a similar normal concrete

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of the same age, and indicates therefore that, with the exception of a very thin layer at the actual surface of contact with the flames, the concrete was uninjured by the test.

Approximately 1½ hours were required in all these tests to develop a temperature of 2 000° fahr. This minimum temperature, with a maximum temperature running up to 2 500° fahr., was maintained for about 3½ hours longer before the application of water.

In the special structures used for these tests, the walls were of brick, 13 in. in thickness, with four flues at each corner. The intake openings below the grate were sufficiently large to induce the necessary draft, and this was regulated by sheet-iron dampers. To produce and maintain the temperatures recorded, an average of about 7 cords of hardwood fuel was consumed, representing a total average depth of approximately 5½ ft. over the entire grate area.

In the average office and hotel building, the combustible contents, which would be consumed in the case of a conflagration, consist of the wood finish, the furniture and the furnishings. If these were all removed and placed in a layer of uniform thickness over the floor area, there would seldom be an average depth of more than 6 or 8 in.; or, approximately, one-tenth of the quantity of fuel consumed in the New York Building Department tests. The intensity of the heat and the duration of the fire in the interior of fire-proof buildings depend upon the conditions of draft and the quantity and character of the fuel or combustible contents. In the San Francisco hotels and office buildings the average duration of the fire in any one room seldom exceeded 20 or 30 min. In special cases, as in supply and storage rooms, the duration of the fire was longer, but the conditions of draft in rooms of that kind were generally such that the fire smouldered and did not burn with as intense a heat. The average maximum temperatures attained in these buildings, as determined by the fusing of metals and other phenomena, ranged from 1 500 to 1 900° fahr. In certain spots where there happened to be more than the average quantity of fuel, and the conditions of draft were favorable, temperatures up to 2 100 and 2 200° fahr. were sometimes reached. These maximum temperatures, however, were not maintained for more than a few minutes in each case.

From the foregoing observations, and on account of the total quantity of fuel that it was possible to consume, it should be apparent, even to an inexperienced person, that the test by fire during the conflagration in the average hotel and office building in San Francisco was comparatively light, and approximately only one-eighth to one-tenth as severe as the regulation fire test made by the New York Building Department. The effect of the fire on the fire-proofing materials, as observed by the writer, was approximately in this proportion. It is patent, therefore, that nowhere near the en-

durance of good fire-proofing material is ever reached in buildings of this class. Mr. Himmelwright.

There were certain structures, of course, such as the Kamm Building, the Sloan Building, and others, in which large quantities of combustible materials were stored. There were also certain rooms and limited areas in other buildings where larger quantities of combustible materials were stored, greatly increasing the duration of the exposure to fire. There were, however, no cases observed by the writer which were exposed to as severe a fire test as the standard tests of the New York Building Department in 1896 and 1897. There were places where a fire burned continuously for from 24 to 36 hours, but the conditions of draft in those cases were not favorable for the production of high temperatures over any considerable areas, and consequently the actual damage to the concrete fire-proofing was not as great as might have been expected. The greatest depth to which dehydration extended, in the most extreme cases observed, did not exceed 1½ in.; while the observations on cinder concrete did not disclose any damage whatever. The last remarks refer, of course, to concrete which was of good quality previous to the fire.

In San Francisco, stone concrete was used for floor construction and fire-proofing more generally than any other. Gravel, steam-boiler cinders and broken brick were also used as aggregates to a lesser extent. Cinders are not used more generally in San Francisco because the ferries and railroads, and some of the power plants, use oil instead of coal as a fuel, and comparatively few cinders are available. There were, however, a number of buildings in which cinder concrete had been used.

In the basement and cellar stories, the metal lath and plaster ceilings were generally omitted, thus exposing the under side of the concrete floors covered with plaster directly to the flames. Generally speaking, there were larger quantities of inflammable materials in the basement stories than in any of the others, and consequently the fire-proof floors directly above were generally exposed to a longer attack of heat than those of the upper stories. Then, again, there were instances, such as in the cases of the Aronson, Young, Scott, and Sloan Buildings, and others, in which there were no metal lath ceilings, or which had such ceilings only in one or two stories. In these buildings, and in the basement stories of others, there was ample opportunity for a careful and intelligent comparison between the fire-resisting qualities of stone and cinder concrete, as well as the relative effects of fire upon the segmental-arch methods and the flat-slab methods, in which steel reinforcing metal was used in tension. There are always sufficient phenomena, such as the fusing of metals, the effect on plaster, brick and stone work, the quantity

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of ashes, etc., etc., from which it is possible to glean a very good idea of the duration and intensity of the heat generated. The inexperienced investigator, however, is very likely to be led to erroneous conclusions by superficial observation. In both Baltimore and San Francisco there were buildings in which the concrete fireproofing appeared to be damaged considerably by the fire, and many intelligent architects and engineers were misled by the appearance of these concretes after the fire. Very few took the time and trouble to seek out a spot where the material had been subjected to very little or no heat and examine the material to ascertain its actual condition before the fire. Wherever concrete fire-proofing has been apparently damaged by a normal attack of fire, such as could be expected in a hotel or office building, the writer has invariably found, on close investigation, that the concrete was of poor quality, and that this fact has been thoroughly disclosed and emphasized by the fire.

The conclusions arrived at by the writer as to the relative fire-resisting qualities of the different materials used for fire-proof floors are set forth in considerable detail in his report on the disaster, entitled, "The San Francisco Earthquake and Fire, 1906," a copy of which is in the Library of the Society. These may be briefly stated as follows:

The segmental cinder-concrete arch, in short spans (8 ft. or less), where the concrete was originally of good quality, developed the best fire-resisting qualities and strength. This material and this form of using it proved vastly superior to any other used for fire-proofing purposes. This method was used in the Hotel St. Francis, and in the ground floor of Haas' Candy Factory, at the corner of Mint Avenue and Jessop Street, and not a single square foot of the floor arching in these buildings was damaged in the least by the fire.

The next best fire-resistance was shown by the short-span (8 ft. or less), cinder-concrete, flat-slab floor construction, in which steel reinforcing metal was used in tension. This method and material was used in the Merchants' Exchange, in which the damage by fire was inappreciable.

The next in order of fire-resistance was the same short-span, flat-slab method of reinforced concrete in which stone and gravel aggregates were used. This method and material was used quite extensively, the best results having been shown in the Mutual Savings Bank Building, the Bush Street and South Offices of the Pacific States Telephone Company, and many others.

The next method in the order of fire-resistance was the reinforced stone-concrete construction proper in long spans, and where rolled-steel girders and beams were generally omitted. Where this method was used, a very slight attack of fire was generally sufficient

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to cause the rupture of the concrete underneath the reinforcing metal, so that it fell away, exposing the metal. There were comparatively few buildings, however, in which this method of construction was used.

The material which gave the least satisfactory results, from a fire-resisting standpoint, was the hollow tile blocks, whether used as end or side construction.

In many of the hotels and office buildings a separate, flat, metal lath and plaster ceiling was erected underneath the fire-proof floors, which is in itself a fire-resisting barrier of considerable value, and a protection that must be taken into consideration in the economical design of fire-proof construction. A well-designed and executed metal lath and plaster ceiling remained in position intact in a New York Building Department test for a period of 4 hours from the time of starting the fire test. This represented a period of 1½ hours during which the temperature was raised from 70 to 1 700° fahr., ½ hour from 1 700 to 2 000°, and 2 hours during which the temperature ranged from 2 000 to 2 300°, averaging, approximately, 2 100° fahr. This ceiling was suspended by clamps or hangers made from steel stock weighing ½ lb. per lin. ft., hooked around both sides of the lower flanges of the beams, at 16-in. intervals; it supported approximately 7 sq. ft. of ceiling surface per hanger. The furring consisted of flat bars weighing 0.6 lb. per lin. ft., set on edge and running through slots in the hangers. The metal lath was stiffened with ¼-in. round steel rods at intervals of 7½ in., and was laced to the furring bars with No. 18 galvanized-steel lacing wire at every intersection of the stiffening rods with the furring bars. These details are important, and are given in order to describe the essential features of a metal lath and plaster ceiling which will give good efficiency. In hotels and office buildings, a ceiling of this character will afford ample protection for the soffits of the floor beams, making it unnecessary to cover these separately with an additional fire-proofing material. This fact also results in a saving in the thickness of the floor construction, and for this reason is an economical feature.

A fact that was demonstrated convincingly in the San Francisco fire was the undesirability of copper wire for fastening metal lath, the much lower fusing point of copper in numerous cases permitting the metal lath to drop away from the supports long before it would have failed had steel wire been used. This fact was particularly noticeable in the James Flood Building and in the rooms damaged by fire in the United States Post Office Building. It has been the uniform practice in the Supervising Architect's Office, during the last 10 years, to specify copper lacing wire for fastening metal lath in all the Government buildings. The ceilings in these buildings,

Mr. Himmelwright.

therefore, cannot be expected to develop the best fire resistance in case of an actual test.

The report of the Committee tends to create erroneous impressions as to the province of metal lath and plaster ceilings, and states that in many cases they protected the concrete floors. While this is true to the extent of their value as a fire-resisting barrier, the concrete floors, when composed of good material, were sufficiently refractory to have made a good record without the ceilings referred to. In the case of the hollow tile blocks, however, where these were protected only by plaster, in nearly every case the soffit members of the tile blocks were cracked away, exposing the cellular spaces. The very general damage of this character indicated that this material possesses poor fire-resisting qualities. Wherever well-constructed metal lath and plaster ceilings were erected under tile blocks, as in the James Flood Building, and in the upper stories of the Spring Valley Building, they prevented serious damage to the blocks. This was demonstrated clearly by the fact that wherever the metal lath and plaster ceilings fell away in spots, the tile blocks directly above were in all cases badly damaged. The tile blocks also showed great weakness and inability to resist the impact of falling bodies on account of brittleness, and numerous safes in the various office buildings very generally fell through the tile floors into the basement, breaking holes through the successive floors under them and sometimes inflicting serious damage to the mechanical plants.

On page 334* of the report the following statement is made:

"The fire shows that a cover of lath and plaster directly upon the flange, protected again by the suspended ceilings, is the best. The layer of plaster alone on the flange will not protect."

In view of what precedes it, this statement, which is typical and characteristic of the report, illustrates the difficulty in arriving at general conclusions. A metal lath and plaster soffit protection is well known to be less efficient than 2 in. of cinder concrete, held in place by metal lath, with plaster applied over that. The efficiency of the metal lath and plaster ceilings and their field of usefulness as fire-resisting barriers, have already been discussed. An actual misstatement, however, is made in the latter part of the above quotation, in that there were several notable instances where a metal lath and plaster soffit protection gave exceedingly good and satisfactory results, namely, in the Kamm Building and the Aronson Building. In both of these buildings crimped or corrugated wire lath was wrapped around the soffits of the beams, the corrugations offsetting the wire surfaces about $\frac{3}{4}$ in. from the beam. This lath was placed in position before the concrete was laid, so that the

Proceedings. Am. Soc. C. E., for March, 1907.

edges were thoroughly anchored in the concrete. After the removal of the wood forms, plaster gauged with Portland cement was applied to the soffits, filling the spaces between the metal lath and the beams solidly with the material and making a total thickness of approximately 1 in. of cement plaster protection. There were no metal lath and plaster ceilings underneath the soffit protection, and in the Kamm Building this method was subjected to as severe a fire as occurred in any of the fire-proof buildings in San Francisco, yet a careful examination of the building immediately after the fire did not show any failure whatever of this soffit protection. The same method was used with good results in the Aronson Building, where it was exposed directly to the flames without any intervening metal lath and plaster ceilings. Mr. Himmelwright.

The report of the Committee goes somewhat into detail in recommending certain methods of fire-proofing columns and other important structural members. While the recommendations given are excellent for certain conditions, the treatment of columns, like fire-proof floor construction, is a question of economical adaptation to the requirements.

The protection to the steel frame, as well as the method used in the floor construction, must in all cases be adapted to the character of the building and the quantity of its combustible contents. A building with floors finished in cement, marble, or other incombustible material, with metal-covered woodwork and only a small quantity of combustible furniture and furnishings, will not require as heavy and efficient protection for the steel skeleton frame as a warehouse, department store, or similar building in which will be stored large quantities of combustible goods and materials. A standard or uniform method of protecting structural members, to be used in all classes of buildings, would not be economical, and would result in a hardship and waste in many cases.

An important fact, which is of interest to architects and engineers, and to which the report of the Committee does not refer, relates to architectural terra cotta. When properly designed, and set in a first-class manner, the results were generally satisfactory. In many cases, however, where the cores were large and the shells of the material were less than 2 in. in thickness, it spalled and cracked under moderate heat.

Another important lesson taught with great emphasis by the San Francisco disaster was the necessity of avoiding all forms of block partitions around stairway and elevator openings. These generally proved to be weak, both in the earthquake and in the fire, and almost invariably failed. The débris from such enclosing partitions fell upon the stairways, frequently breaking them down and causing irreparable damage. The failure of the block partitions also precipitated large quantities of blocks into elevator

Mr. Himmelwright.

shafts, damaging the framework and doors, and often injuring large portions of the mechanical equipment in the lower story. A reinforced-concrete partition with vertical steel members anchored to the beams, or fire-proof construction at the top and bottom, is vastly superior and preferable for enclosing openings of this character.

The writer is greatly surprised at the statement made by the Committee in its final conclusions on page 333* to the effect, "that the destruction of fire-proofing must be expected, and that it will have to be restored after a fire."

There is absolutely no question that, at the present time, methods and materials are available for fire-proofing purposes which are thoroughly efficient and will fulfill the various requirements for different classes of buildings in an entirely satisfactory manner. By this is meant that when suitable methods and materials are used and adapted intelligently to the requirements of any particular building, such fire-proofing will not be damaged seriously by the combustion of the inflammable contents of the building in the case of a fire. The efficiency of first-class methods and materials has been demonstrated in full-sized fire and water tests made at different times in the past, and numerous examples of entirely satisfactory fire-proofing were to be found in both the Baltimore and San Francisco conflagrations.

To reach correct and intelligent conclusions, and make definite progress in the development of fire-proof construction, it is necessary to exercise intelligent discrimination and adopt that which is good and which has proven efficient in actual test by fire; and discard and abandon that which has failed or proved deficient. This principle was followed by the writer in his report, already referred to. By giving complete, detailed descriptions of the methods and materials of construction in the instances of satisfactory fire-proofing, some of which have been referred to in the report, such as the concrete column protection in the St. Francis Hotel, the Shreve Building, and others, and the fire-proof floor construction in those buildings where good results were shown, definite information would have been available to assist architects, engineers, and others in designing efficient fire-proof construction for future buildings. Unfortunately, the report of the Committee is absolutely devoid of such detailed information, and an exceptional opportunity for rendering a public service has thus been lost.

There is, finally, a phase of this subject which has not yet been touched upon—the commercial side. The writer's long experience in the business of contracting for fire-proof construction has afforded exceptional opportunity to study the attitude of capitalists, owners, and architects on this subject. It will no doubt be a sur-

* *Proceedings*, Am. Soc. C. E., for March, 1907.

Mr. Himmelwright.

prise to many to learn that in more than 95% of the fire-proof buildings erected during the last five years the mistaken economy of owners and their representatives has prevented the adoption of good fire-proof construction in that proportion of buildings. In every case the difference between a poor and mediocre method of fire-proofing and a first-class and efficient method has not been in excess of from 2 to 4% of the cost of the building. As long as a cheap method or system of fire-proofing complies with the building laws of the city in which the building is to be located, and fulfills the requirements for strength, the average owner is satisfied, and is unwilling to appropriate any additional money whatever for superior methods or materials. It is the same old story of "just as good" substitution.

When the owner, as is generally the case, has no practical knowledge of building construction, and is incapable of judging of the merits of different methods and materials, he invariably adopts the lowest-priced method or system offered, or instructs his architects or representatives to do so. One of the incomprehensible things is the further fact that the average owner, or his business representative, thinks that he is fulfilling every moral and business obligation by offering to award the work to the concerns furnishing first-class and efficient methods at the same price that the poorest and cheapest methods are offered to them. This policy and method of placing contracts for fire-proof construction is used almost without exception, even by large railroads and wealthy corporations.

In the case of all other building materials, such as stone, brick, steel, cement, etc., quality is carefully considered, and the prices are graded accordingly; but in the consideration and selection of fire-proof construction, which is probably the most important detail of a modern building, quality and efficiency have been entirely neglected up to the present time.

As long as owners and architects are unwilling to pay the small additional amount necessary to secure first-class fire-proofing they must expect results such as were shown in Baltimore and San Francisco whenever a conflagration of any magnitude occurs. It would seem, however, that the exercise of the most ordinary intelligence would prompt the owner of a valuable building to expend from 2 to 4% of its cost, in order to secure exemption from damage to the structural parts of the building, and an additional 5% for the protection of exterior window and door openings, in order to save the contents of the building from exterior attack by fire.

It is to be hoped that the recent great disasters in Baltimore and San Francisco will serve to show the great importance of recognizing merit and quality in fire-proofing methods and materials, and demonstrate the necessity, as well as the ultimate economy, of using first-class and efficient methods of fire-proofing in future buildings.

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PAPERS AND DISCUSSIONS.

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THE REINFORCED CONCRETE BRIDGE ACROSS THE HUDSON RIVER AT SANDY HILL, NEW YORK.

Discussion.*

BY MESSRS. HENRY H. QUIMBY, C. L. SLOCUM, D. L. KRELLWITZ AND E. W. STERN.

Mr. Quimby.

HENRY H. QUIMBY, M. AM. SOC. C. E. (by letter).—This bridge is an interesting illustration of the economic and æsthetic advantages of concrete as a material of construction. A steel-girder structure with paved deck would have cost more—the $72 000 would scarcely have paid for the superstructure alone—and the cost of proper maintenance capitalized would add a very considerable percentage to the total. Its appearance—its architecture—is also very pleasing, and the bridge will be a lasting delight to the community served by it.

The paper, while presenting the novel features and discussing the important points of the design, is somewhat meager in respect to several matters in which designers of concrete arches are especially interested. The stress diagram, and the method used in computing the stresses in the steel and concrete, including the temperature stresses, would add much to the value of the paper, as would also the details of the cost—the quantities and unit costs of the several divisions of the work.

*This discussion (of the paper by William H. Burr, M. Am. Soc. C. E., printed in *Proceedings* for April, 1907), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Quimby.

The advantage of locality, of the proximity of the raw materials, may have been considerable, but, even then, the management must have been very efficient, for the cost of the work seems to have been quite low and the time consumed remarkably short.

The stresses in the arch due to changes of temperature will be high at the crown and at the spring, the whole effect of the change in length of arch, and the consequent rise and fall of the crown, being concentrated at these three points because the intermediate stretches are held rigidly to shape by the spandrel walls, unless the latter should be ruptured. The author's analysis of this effect would be valuable. The paper states that the bridge is designed to carry the specified loads without exceeding a compressive stress of 500 lb. per sq. in. in the concrete, and that, for all ordinary loadings, even with the prescribed railway loads, that compressive stress does not exceed about 400 lb. per sq. in. It is not clear whether the difference between the two represents the temperature stress, or whether the higher is merely the extreme fiber stress at the greatest eccentricity of the center of pressure.

The order in which the concrete was placed is an important consideration. If the soffit sheathing, in which was embedded the rods anchoring the block-built outer ribs to the inner ribs, was not constructed at the time of grouting the blocks, an opening between the blocks and the sheathing is possible, thus admitting water and subjecting the anchors to corrosion and ultimate destruction. The method of placing the rib concrete and that of the walls affects the question of initial stresses in the material, which, when combined with temperature stresses, are undoubtedly sometimes the cause of spalling and cracking.

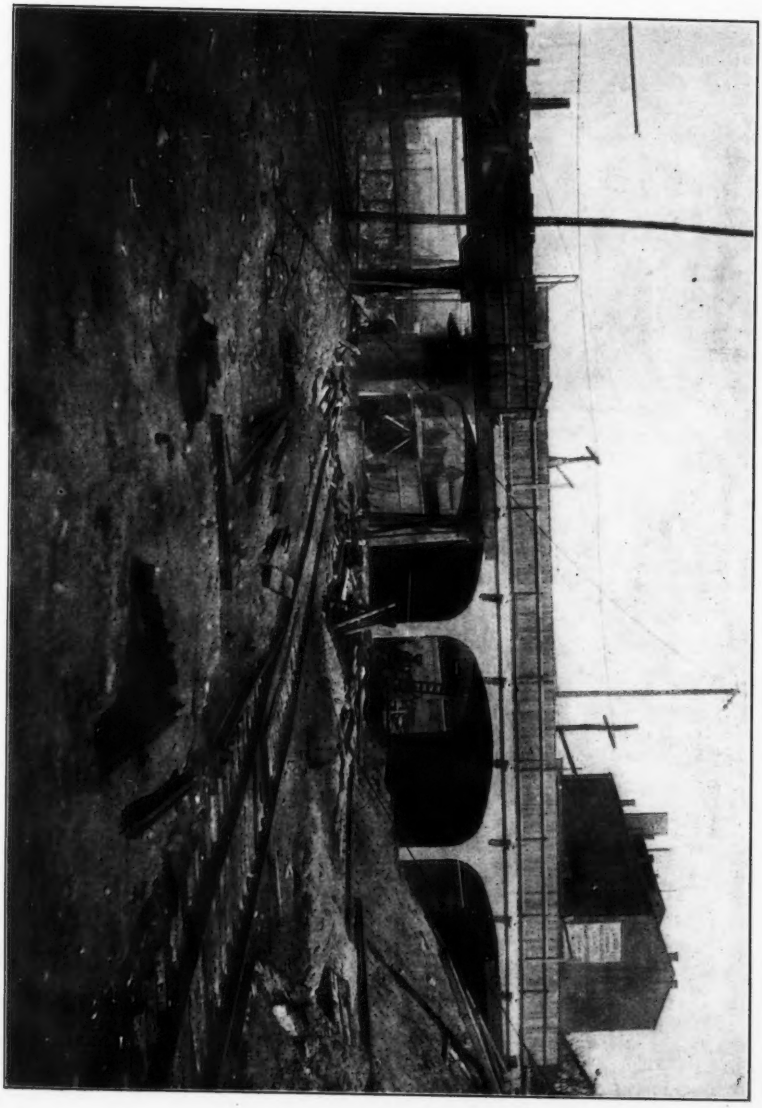
The transverse reinforcement of the interior spandrel walls is novel, and will probably not be generally regarded as necessary. The cleavage that such reinforcement will resist is only longitudinal, either vertical as a spilt or diagonal as a shear of a column in compression, and such thin walls should not be subject to the former, and these are stressed so low vertically that the latter should not be feared. A very efficient reinforcement in the same direction would be flat stones embedded horizontally in the walls. This is found to add to the compressive strength of the concrete, and also to be economical, for the extra labor of placing is more than offset by the saving of cement concrete.

The channel sleepers under the track rails seem to be merely bedded on the concrete. If they are not bolted down firmly they will be likely to give trouble by loosening and pounding. It has been found necessary in this class of track construction to hold the rails down firmly to a solid bearing on the concrete to prevent chattering, thus pulverizing the surface and corrugating the rails.

Mr. Quimby. The wisdom of the plan of construction—block facing built up several courses and then grouted, and afterward filling in the heart with concrete which pretty certainly will shrink away from the facing—will not be generally conceded. Shrinkage openings, as well as the almost inevitable voids that the grout will fail to fill because of entrapped air and other stoppages of flow, will be likely to collect water, which is a destructive agent in all masonry; and the claim made in the paper that the construction is monolithic is hardly warranted. The economy of the method is open to question, which, however, should be answerable by the record of cost on this work compared with the fairly definitely known cost of wooden forms. The other expressed purpose of the adoption of this system of construction—to produce a satisfactory surface finish—could have been easily accomplished in monolithic work by removing the face forms within a day or two of placing the concrete and then scrubbing off the film from the surface, leaving the aggregate exposed to view. The result of this treatment is a face which is stone-like in texture and wearing quality, and not subject to the discoloration which mars a cement surface; or the face might have been tooled to remove the film, thus obtaining a surface which would be quite pleasing.

Mr. Slocum. C. L. SLOCUM, Assoc. M. AM. SOC. C. E. (by letter).—The somewhat novel methods of design and construction used by the author, in this bridge, are of especial interest to the profession. The method followed in making each arch or series of arches independent and self-supporting, without leaving the falsework in place until the completion of the abutments, or providing an abutment support or its equivalent to withstand the dead-load thrust of the completed arch spans, has many distinct advantages, particularly in places where of necessity only a portion of the bridge can be built at one time. This is especially true where a series of arches span railroad tracks in constant use, and where all the room desired is not to be had.

Such conditions have been encountered in New Haven, Conn., in the construction of the arches of the reinforced concrete highway bridges of the New Haven Improvement of the New York, New Haven and Hartford Railroad. Here each highway bridge consists of four or five solid spandrel arches, each arch spanning a pair of tracks. In this improvement, in which the tracks are in a depression or cut, other recourse could not be had; there was not enough room to shift traffic from the site of the new structures, and besides, these highway bridges are so close to one another that certain spans in four of the five bridges of this class, have to be constructed to receive the tracks for traffic before the remaining spans can be completed.



REINFORCED CONCRETE HIGHWAY BRIDGE OVER TRACKS OF THE NEW YORK, NEW HAVEN AND HARTFORD RAILROAD.

Mr. Slocum.

The writer is of the opinion that, in most cases, fabricated units, or firm steel skeletons, are preferable to a less firm framework of rods and ties for reinforcement, especially in this and similar cases. In this particular construction, the fabricated units are made of old rails held together as rigid frames by old fish-plates and bolts, and bent-plates and bolts; longitudinal and transverse rods and vertical ties form a secondary meshwork between the built-up frames. In the design of this reinforcement, the writer, in addition to providing enough steel in the piers to take up the bending of the thrust at the springing line, giving an independent arch, has gone a step further. The frames of old rails are spaced so that, if it had been necessary, the usual kind of falsework, which is being used as a conservative measure, could be omitted, the lagging being hung from or attached firmly to the rail reinforcement. In other words, it is entirely feasible to erect these arches over tracks which are in constant use. Some European engineers, in design and construction, make the frame reinforcement large enough and strong enough to carry the requisite lagging and adjuncts. It is not at all improbable, in particular cases, that the saving in the cost of forms is greater than the increased cost of the added steel area required for self-support.

The general and detailed features of this construction have been described more fully in the technical press; however, by explaining the photograph, Plate LXXIV, perhaps what has already been stated will be better understood. The present main-line tracks at the extreme left of the photograph occupy the space necessary for the last arch and abutment. The arches are 31 ft. in the clear; the solid piers are plumb, and 2 ft. thick at the springing line. The last pier to which the remaining arch span is to be constructed is notched or cut out at the springing line to receive the last span. It is 12 in. thick at this point. The arch rail frames project out from this notch, and are connected to the vertical rail reinforcement which occupies the center of the pier. One side of this vertical rail reinforcement above the notch is barely covered with concrete, and the edges of the flanges of the rails are exposed in several places. There are frequent rabbets and other additional projecting rods of the meshwork to provide a good bond for the connection of the last arch. In addition to its own weight, this bridge, as shown in Plate LXXIV, has a temporary 7-ft. enclosed sidewalk which, during the noon hour, is quite congested with people from the nearby factories, etc. The main-line tracks are nearby, and although there is the usual tremor caused by trains passing frequently, there are no signs of weakness at this critical point, and none are expected.

Mr. Krellwitz.

D. W. KRELLWITZ, JUN. AM. SOC. C. E.—Professor Burr has given a most interesting description of this bridge, which is re-

Mr. Krellwitz. markable for its block construction. The architecture rendered by such block construction is very good when one considers the small sum of money expended for beauty and strength combined. The details and sizes are of considerable interest, and show clearly a good design. The speaker would like to ask what the deflections were at the crown of each of the fifteen spans when the centering had been removed?

Mr. Stern. E. W. STERN, M. AM. SOC. C. E.—Would Professor Burr be so kind as to state how the thrust of one of the arches would be provided for, if the adjoining arch were removed?

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WATER SUPPLY.

An Informal Discussion at the Annual Convention, July 10th, 1907.*

SUBJECT FOR DISCUSSION:

"Is it better policy to purchase and control water-sheds, thereby preventing the pollution of impounding reservoir supplies, or to suffer a certain amount of pollution of such supplies, relying upon filtration to correct the effects thereof?"

BY MESSRS. GEORGE W. FULLER, F. HERBERT SNOW, D. D. CLARKE AND GEORGE A. SOPER.

GEORGE W. FULLER, M. AM. SOC. C. E. (by letter).—Various local conditions require consideration, in deciding this question. This is particularly true as to the quality of water which it is desired to obtain, which quality must meet, or ought to meet, certain rational requirements of local or State health authorities. Mr. Fuller.

It is undoubtedly true that water supplies which were believed to be good 10 years ago are not in all cases now regarded as satisfactory in quality. As to water supplies of good quality to-day, there are strong reasons for believing that some of them will not necessarily be thus regarded a few years hence. We are in a transitional stage as regards the quality of public water supplies. Advanced positions taken by various health authorities and by public opinion, without doubt, now make it urgent for the engineer to be keenly alive to sanitary requirements, in order that public water supply projects may keep abreast of the times.

* Further discussion, had at the Convention, will be published subsequently, and additional written discussions are invited.

Mr. Fuller. The basic thoughts or premises should first be stated, in order to facilitate discussion, and, as they appear to the writer, they may be outlined briefly as follows:

1.—It is essential that the water from impounding reservoirs, or from any other source, shall be substantially free from disease-producing germs.

2.—A satisfactory public water supply should be of good appearance and free from objectionable quantities of mud, turbidity, and vegetable stain.

3.—A satisfactory water supply should be free from objectionable tastes and odors.

4.—Impounding reservoirs are of much assistance in the purification of water through natural agencies, as regards the removal of bacteria, turbidity, and peaty color. Their agencies are not infallible, and their efficiency varies much with different conditions as to rainfall, temperature, climate, storage period, and other physical factors.

5.—The elimination of pollution through the purchase of land is highly desirable, but in many places is prohibited by its cost. Sanitary control through inspection is helpful, but difficult of accomplishment under existing laws and customs.

6.—A well-designed and well-operated filter plant, with all its various appurtenances, such as efficient aeration, sedimentation, and coagulation, will allow a satisfactory water to be obtained from practically any impounded-water supply, although, within certain limits, the better the quality of the unfiltered water, the better and cheaper will be the filtered water.

Protection by Impounding Reservoirs from Disease Germs.—Where a reservoir has a capacity equal to the volume removed from it during a period of many weeks or months, it is obvious, from our present knowledge, that a large proportion of the disease germs will disappear from the flowing water. These germs have weight, and subside in fairly quiet water. According to laboratory experiences, disease germs live much longer in reservoir water than in sewage or highly polluted waters.

In all waters there is quite a rapid dying out of disease germs during the first week or so, and, with present laboratory methods, it is usually very difficult to detect the presence of any of these germs after they have been in water for two or three weeks. This does not prove, however, that all the germs have died out. On the contrary, the evidence seems to be quite strong that some of the more hardy ones, perhaps only a fraction of 1% of the total number, will survive for a long period, presumably months and years. Otherwise, it seems to be impossible to explain the continuance of water-borne diseases in certain districts.

Mr. Fuller.

While our knowledge of the passage of disease germs through large impounding reservoirs is by no means precise, our information is such that we cannot ignore certain physical conditions limiting the efficiency of the natural agencies there at work. Among such are the stirring up of the bottom layers of deep reservoirs, due to vertical circulation during each spring and autumn, and the effect of stratification and of various currents, which, under some conditions, no doubt bring the entering water to the outlet in an abnormally short period of time.

It is futile to go into this subject in great detail here, but it is to be pointed out clearly that because a reservoir may hold 100 days' supply it by no means follows that the numbers of disease germs passing through the outlet are always as low as would result from the stay of these germs for 100 days in the reservoir water. Obviously, the protection from impounding reservoirs increases with the period of effective storage.

There are other factors also to be considered. Among them may be mentioned heavy rains, which sometimes wash into the impounding reservoir the accumulated filth of weeks and months, and also that such pollution may at intervals occur when the reservoirs are drawn down quite low, and when the opportunity for purification by natural agencies within the reservoirs is abnormally small.

Let us next turn to the question of how much pollution may suffice for impounding reservoir waters to produce disease among the consumers. The evidence is quite striking that the dejecta of one or two persons suffering from typhoid fever or other serious intestinal disorders may pollute surprisingly large volumes of water. This is particularly true when such dejecta accumulate during the winter months and are suddenly washed into the stream or reservoir when there is a general thaw. Experiences at Plymouth, Pa., New Haven, Conn., York, Pa., Scranton, Pa., and other places, show that the danger from a scattered population on the water-shed may at intervals be far greater than was considered possible a few years ago.

Notwithstanding its shortcomings, the impounding reservoir has been and continues to be a tower of strength in municipal sanitation in many places. This becomes quickly apparent upon comparing the typhoid death rate (about 20 per annum per 100 000 population) in New York, Newark, Jersey City, etc., which is as low as in numerous other cities more or less similarly situated, and having a public water supply either from underground sources or of filtered river water.

Filtration of upland water from sparsely populated areas, however, produces still lower death rates in some cases, as shown by the experiences of Paterson, N. J.

Mr. Fuller.

Mortality statistics as to typhoid fever and other water-borne diseases are frequently only a very rough measure of the quality of a public water supply. This is particularly true of waters which are of fairly good character. Pollution may exist at times without its presence being recognized. This is probably true at intervals in the case of the Croton supply. Early in the spring of 1907 there was a small outbreak of typhoid fever in New York City, stated by Health Commissioner Darlington to have been caused by Croton water.

One of the weaknesses of the impounding reservoir is that its inefficiency cannot always be detected or corrected in time to avert danger. This accentuates the importance of more attention being given to one or both of the procedures advanced in this theme for discussion, namely: the prevention of pollution on the water-shed, or its correction by filtration.

Protection by Impounding Reservoirs from Unsatisfactory Physical Condition of Water.—Sedimentation in large impounding reservoirs usually produces sufficient clarification, and it is only at times of exceptionally heavy rainfall that the water is muddy when delivered to the consumers. As compared with the waters in large rivers, especially in the South and West, the impounded supply is quite satisfactory in this regard.

The remaining turbidity in the water drawn from an impounding reservoir, however, is usually due to very fine particles, dark in color, which produce what is called a "dirty appearance" in the water; this is frequently complained of much more than would be expected by the users of muddy river waters.

In the case of waters drawn from drainage areas containing more or less swampy tracts, the impounding of the water does much to bleach it by the aid of sunlight, and to lessen materially the brownish tint due to organic matter extracted from leaves and other vegetation.

It is with regard to tastes and odors that the most disagreeable physical conditions are likely to be encountered in the water of an impounding reservoir. These may be due to the decomposition of organic matter on the bottom of deep reservoirs, or to the growth and disintegration of various small forms of vegetable and plant life which make their appearance in reservoir waters in a more or less irregular fashion and in a manner not now fully understood.

The stripping of the bottom and sides of reservoirs does much in the early life of a reservoir to reduce the likelihood of bad tastes and odors due to vegetable growths. It is not an absolute safeguard against these troubles, however, and it is to be further pointed out that the effect of stripping is not wholly permanent in its nature. In fact, present evidence indicates that soil washings,

Mr. Fuller.

in course of time, perhaps 10 or 20 years, will largely obliterate the effect of stripping.

When it is considered that a public water supply ought to be thoroughly "clean," it can hardly be maintained, in the light of modern requirements, that an ordinary impounding reservoir can give uniformly a thoroughly satisfactory supply in the absence of filtration, or of aeration, or of both.

It is true that swamps may be drained and various other expedients resorted to, but it is not ordinarily possible, in the opinion of the writer, fully to meet modern requirements as to the physical conditions of water through the agencies which act in the ordinary impounding reservoir. There are, of course, exceptions to this rule, and some exceptions will no doubt continue for a long time to come. The experiences and conclusions, however, at several places where bad tastes and odors prevail, show that, independent of pollution upon a water-shed, filtration is highly desirable and well worth its cost. The fact that trouble from microscopic growths has not yet been experienced in any given impounded supply is no proof that difficulties will not arise in the future.

Protection by Filtration.—For the most part, filtration has been practiced in America in connection with muddy and polluted river waters. For impounded water supplies, sand filters have been used successfully for two of the gravity supplies at Reading, Pa., the Ludlow supply at Springfield, Mass., and have been introduced recently at Bar Harbor, Me. Impounded water supplies have been treated satisfactorily by mechanical filtration at a number of places, among which may be mentioned Lexington, Ky., Middletown, N. Y., Norfolk, Va., and Charleston, S. C.

Available evidence shows clearly that by filtration a water can be made thoroughly satisfactory as to freedom from disease germs and objectionable tastes and odors, as well as of satisfactory appearance. Modern filter plants, both in their construction and their operation, require close adjustment to existing local conditions, and are bound to vary somewhat in their detailed arrangements. Filtration, in this discussion, is viewed in its broadest light, and with it is included efficient aeration and the use of coagulants when necessary.

As to the cost of filtration, that of an installation, complete, with all appurtenances, usually ranges from $15 000 to $30 000 per million gallons daily capacity. Usually, the figures for impounded reservoir waters would be nearer the lower figure, although there are special conditions in some places which require the higher figure to be exceeded. The cost of operating filters of moderate size usually ranges from $1.50 to $3.50 per million gallons for reservoir water, exclusive of pumping. Combining the operating expenses and capi-

Mr. Fuller. tal charges, taken at 5% per annum, there is obtained, for fairly representative conditions, the sum of $7 per million gallons. On the assumption that 100 gal. of water are used daily by each inhabitant, this would mean a total annual expense of about 25 cents for each inhabitant.

Filters ordinarily remove from 97 to 99.5% of the bacteria in the applied water. Where bacteria have been removed to a large extent by sedimentation in impounding reservoirs, the numbers are sometimes so low in the unfiltered water that the above percentages are not obtained. The residual number of bacteria, however, would be very low, and the water would be fully equivalent in hygienic quality to the above stated percentages of removal as we understand them in connection with practical operations in the filtration of river waters.

Filters are not germ-proof, and none of their warmest advocates claims them to be. Their efficiency has proved a tower of strength in municipal sanitation in the past—even greater than that of the impounding reservoir—notwithstanding the fact that a small fraction of the applied bacteria passed through the filters and appeared in the water supplied to the consumers.

Obviously, the more polluted the unfiltered water is, the less safe will be the filtered water. The logical question in connection with this discussion is this: To what extent can water-sheds be purchased and controlled, with the result that the water is made of thoroughly safe quality, and under conditions where the investment on the water-shed is preferable to an investment at a filter plant?

Two fundamental things are to be borne in mind: First, that, all things being equal, a pure water is better than a purified water; and, second, that by adjusting the rates of filtration, by double filtration, and by the use of germicides, it is perfectly practicable for filtration experts to deliver to the consumer almost any grade of filtered water that is wished, provided the purification works are built and operated strictly in accordance with the best available knowledge of sanitary science.

This brings us to the question of relative safety, and the reliability of human efforts, both as regards the control of water-sheds and faithfulness and efficiency in the operation of filtration works.

Comparative Cost and Reliability of Preventing Pollution on the Water-shed and of Removing Pollution by Filtration.—Data are available to permit, for any specific case, a fairly close estimate of the comparative relations of these factors. It is difficult, however, to generalize on this question, owing to the varying local conditions, and they will be treated in this discussion in an illustrative way.

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The total cost of efficient filtration may be taken at an average figure of about $7 per million gallons per day, including interest, sinking fund, repairs, replacements, and operating expenses. This is equal to about $2 500 per annum, corresponding to about $50 000 as the sum required for the maintenance of filtration works of a capacity of 1 000 000 gal. daily in perpetuity.

A water-shed area corresponding to a dry-weather yield of 1 000 000 gal., of course, depends much upon the rainfall, the evaporation, the relative capacity and water surface of the impounding reservoirs, etc. For purposes of illustration, let us assume that 1 000 acres of water-shed area are required for the development of 1 000 000 gal. of water daily. This means that, for the purchase and control of water-sheds, there would be available about $50 per acre, in order to have the cost of such treatment approximate that of filtration.

Where land is cheap, the water-shed area small, and the reservoir capacity large, there is merit in purchasing the entire land in some cases. For projects of moderate size, the writer believes that the likelihood of such purchase doing away permanently with the needs for filtration is too remote to be considered seriously.

Based on the above assumptions as to cost, it is seen that, for large water-sheds, where there are numerous villages, fertile farming lands, and desirable locations for country residences, it is hardly feasible to purchase the entire water-shed for anything like the sum which would permit efficient filtration to be maintained for all time.

If the costs were equal, and only one procedure were to be adopted, it is the writer's opinion that filtration would be preferable, not only on hygienic grounds, but for the sake of assuring a water supply of suitable physical character at all times.

In this it is to be borne in mind that filters have been installed recently at Bar Harbor, Me., notwithstanding the fact that there are no regular residents upon the water-shed, although it is stated that there are some three or four summer camps. Bad tastes and odors required the adoption of filtration.

As to the purchase of those lands upon which there are sources of objectionable pollution, and the control of the remainder by sanitary inspection, the writer is aware that this can be done with much benefit upon small water-sheds, but that it is frequently difficult to secure satisfactory results on large water-sheds by purchase and control.

The City of New York has undoubtedly benefited to a considerable degree by the elimination of objectionable sources of pollution upon the Croton water-shed, through the purchase of large numbers of small tracts of land, especially along the watercourses. However, the writer is keenly appreciative of the limitations to

Mr. Fuller. these methods as applied to the Croton water-shed of 360 sq. miles of drainage area.

Italian settlements on low, wet land may be purchased to-day, but they will certainly spring up again to-morrow in almost equally objectionable locations.

Sanitary inspectors may provide thoroughly sanitary arrangements for the removal of fecal discharges, but of what avail are they with a population whose habits are such that they will not use these sanitary conveniences, and whose lack of education is such that they persistently and regularly resist efforts to protect both themselves and the users of the water from the drainage area upon which they are resident?

Several things must be corrected before the purchase and control of water-sheds for large projects can approach the efficiency of filtration when conducted with moderate intelligence and skill as practiced in numerous places to-day.

A compaign of education is required, not only for the Italian on the Croton water-shed, but for many others whose views would no doubt respond to educational efforts to correct their ignorance and indifference. Such corrections will assume practical shape largely in proportion to the vigor with which wise sanitary laws are carried out promptly, and with a firm hand to administer proper punishment in an equitable manner, and about which there can be no dispute as to the division of responsibility between State departments of health, municipal departments of health, and municipal water departments.

The history of sanitary control of water-sheds in America, in the opinion of the writer, shows that it does not offer nearly the protection to the water consumer that is afforded by modern filtration. Sanitary control has been of great help in numerous places, but there are other instances where laws are inefficient, residents on the water-shed careless and indifferent, and where efficient results are more or less confined to the period when the inspector is actually on the premises. Better laws, better and larger organizations for sanitary inspection, and a better understanding by the residents of what is required can no doubt bring about improved results in the future.

While the writer is not in favor of sanitary control to the exclusion of filtration, he is clearly of the opinion that more stringent sanitary laws than now exist in most places should provide for the removal of all gross pollution, and that simple, practical methods should be gradually introduced to eliminate uniformly the lesser pollutions in the order of their importance.

Mention should be made of the reliability of filtration as actually carried out in practice. A decade ago many filter plants were such

in name only. The last few years have seen a marked change for the better. Practically all the larger filters are now well designed, and are arranged so that they can be controlled readily by intelligent, faithful attendants. Most important of all is the almost universal custom of installing laboratories at the filters, and of placing the operations under constant technical supervision. In no branch of sanitary engineering has more progress been made lately than in the efficient management of water filters for the larger cities. Mr. Fuller.

In the future, such management will certainly continue, as it will doubtless be obligatory to furnish frequent and full records of the results of operation to supervising State authorities.

Compared with sanitary inspection, scattered at different points over a water-shed, and in the hands of various individuals, it appears to the writer that there is far less likelihood of inefficiency in the operation of filters, centrally located, with the management under a single roof, and in the hands of a single person.

European Tendencies.—In Germany, where for a dozen years filtration has been practically compulsory for surface-water supplies, there are only a very few important cities which derive their water from impounding reservoirs. In Great Britain, however, there are many such supplies, and it is significant that the majority of the engineers having charge of new impounded-water supplies have provided not only for filtration, but also for the purchase of the water-shed, where this can be done at moderate cost. Fortunately, such purchase has been practicable, and has been carried out, at the new water-works of Liverpool, Birmingham, Swansea, Cardiff, Manchester, Edinburgh, etc. Land on these drainage areas is comparatively inexpensive, and the writer thinks that there is no room for doubt about the wisdom of eliminating at nominal cost all sources of pollution from a resident population.

There are various reasons why it is usually difficult in America both to filter and to purchase or control the water-shed, notwithstanding the desirability of doing both, from a theoretical standpoint. It is even necessary in some cases to install filters for polluted streams, when impounded-water supplies could be availed of as far as physical conditions are concerned. Under such circumstances, it is the writer's practice to arrange the filters so as to serve for the upland supply when financial and other conditions will permit its adoption.

Conclusions.—1.—The purchase and control of water-sheds is a less efficient procedure than filtration, as regards both the sanitary character of the water and its physical condition as to appearance, tastes, and odors.

2.—For projects of much magnitude, filtration is generally the cheaper.

Mr. Fuller. 3.—Sanitary control of a water-shed is of much assistance, but it is usually a difficult matter to manage well at all times for large water-sheds, under existing conditions as to sanitary laws, and as to the views and responsibility of rural population. Better laws are generally needed.

4.—The purification of water due to natural agencies in a large impounding reservoir makes its filtration easier, cheaper, and more effective than in the case of the ordinary river water. Purification plants can be installed to insure almost any degree of efficient purification that is desired.

5.—Notwithstanding the efficiency of filtration at reasonable cost, there is a growing tendency in America to provide as good sanitary conditions on a water-shed as practicable. As a rule, it is not believed that the purchase of the entire water-shed is advisable, on the ground that the money involved can be expended better in other ways.

Mr. Snow. F. HERBERT SNOW, M. AM. SOC. C. E. (by letter).—The sanitary conservation of public water supplies is a subject which forced itself upon the attention of the General Assembly of the State of Pennsylvania in 1905, resulting in the enactment of a law entitled "An act to preserve the purity of the waters of the State, for the protection of the public health," under which the Commissioner of Health is administering that branch of State medicine relative to public water-works and sewerage in a way to prevent ultimately a recurrence of epidemics of a water-borne character.

During the winter of 1906-07 three notable epidemics occurred in Pennsylvania, namely, at Scranton, Warren and Kittanning. Prior to this time the State had furnished the classic typhoid fever epidemic at Plymouth, and later at Butler. The facts in connection with these cases and the lessons they have taught should be clearly in the mind of the expert called upon to advise with respect to the amount of sewage pollution permissible on a water-shed.

The Scranton typhoid scourge came from an unfiltered surface supply of water derived from a mountain water-shed on which were located three villages and two railroads. The disease struck the town suddenly, lasted about 6 weeks, totaled over 1 000 cases and rolled up a record of over 100 deaths. No infection could be found on the water-shed. The poisoning of the water must have been accidental, but, nevertheless, it was certain. Typhoid bacilli were discovered in one of the reservoirs.

The lower basin, from which the gravity supply mains extend to the town, has a capacity of about 100 000 000 gal. The main impounding reservoir is 5 miles above, and has a capacity of over 1 000 000 000 gal. A short distance above is a third impounding reservoir having a capacity of about 400 000 000 gal. Extending for

several miles along and across the main stream, and by the shores of the three reservoirs, are the two railroads. Droppings from the passenger coach closets might easily have been washed from the roadbed into the city supply. Mr. Snow.

Although these and numerous other permanent menaces had existed on the water-shed for years, Scranton had never before been afflicted by a water-borne disease. Whatever pathogenic pollution had reached the reservoirs was either effectually destroyed by natural agencies or rendered impotent. Retention in the impounding basins must have been one of the formidable barriers against the entry of infection into the water pipe system. No doubt is entertained about such infection having been present in the city supplies prior to the epidemic. The topographical evidences are conclusive.

It was not due to improper operation of the water-works plant, or to any apparatus or appurtenance thereof, that the flood gates of disease were let down in this instance. Simply this: there came a day when all the natural barriers proved of no avail. Without any change in the physical conditions on the water-shed, and without warning, Nature's safeguards went down. What had proven for thirty years or more to have been an adequate plant for furnishing a pure and wholesome supply suddenly became inadequate, thereby transmitting disease and death to the community. The origin of the infection will probably never be known.

An intelligent mind cannot reflect on the history of this catastrophe without being impressed by the lesson it teaches. Barriers against water-borne diseases, to be effective under all conditions, should be capable of manipulation and control. The water company had purchased several hundred acres along the streams and around the reservoirs, and had attempted to control the water-shed by a system of patrols constantly maintained. Many nuisances were thus abated and some prosecutions made to prevent the pollution of the impounding reservoir supplies. During the epidemic, the State assumed control of the water-shed, and put in force rigid rules and regulations for the sanitary protection of the waters thereof. There are scores of public water-works systems to-day where the sources of supply are as likely to be infected, accidentally or otherwise, as the Scranton source, and even more so. Many human lives are bound to be sacrificed before adequate and universal preventive measures shall have been adopted.

At Warren, beginning on December 8th, 1906, an epidemic of gastro-enteritis raged for four days, during which 1 200 patients called for medical attention, and about 600 more were reported bedridden, but did not receive professional care.

This borough takes its water supply from driven wells, in the

Mr. Snow. town, on the banks of the Allegheny River, the waters of which are polluted by sewage. Investigations by the Department of Health pointed conclusively to the water as the medium of transmission of the poison. From the nature of the ailment, it was premised that the infection must have been in concentrated form.

The cause was discovered to have been the sudden rising of the river and the back-flooding of sewage through a drain pipe and ultimately through loosened joints of the piping of the driven-well system and into the town's supply. Attention to the sewer, which was in a leaky condition, and to the joints and packing of the suction pipes, which joints and packing had been loosened by alterations in the main suction pipe, would have prevented trouble. Too much care cannot be exercised with respect to the condition of the apparatus by which ground-water is obtained for a public supply, when such apparatus is located on the banks of a sewage-polluted river in which freshet heights inundate the surface of the land upon which the wells are located. The danger exists if there be sewage in the river, or a conduit, or a receptacle, or anywhere whence it may be transmitted to the drinking water. The lesson taught by this experience is that a ground-water supply, regularly proven by tests to be of superior quality, may suddenly become contaminated from a known remote source, and be prejudicial to the public health. The remedy, therefore, if it be practicable to do so, is to remove the remote danger, in other words, to pay attention to the proper disposal of sewage.

The sewers of Warren discharge into the Allegheny River about 90 miles above the borough of Kittanning, in which the source of public supply is the same river. The water was filtered, and was supposed to be purified. However, expert investigation revealed the fact that the plant had not been operated intelligently, nor was it equipped to render satisfactory treatment of the water possible. Yet the public was led to believe that the system of purification as installed and operated was a sufficient safeguard.

Several days after the Warren outbreak a similar epidemic of gastro-enteritis broke out in Kittanning. It lasted more than 8 weeks and numbered in that time upwards of 4 000 cases. The physicians of the borough reported that the vast majority of citizens were afflicted and received medical attention.

Pathogenic pollution from many municipalities on the banks of the river above Kittanning may arrive at the water-works intake at the latter place in condition capable of causing disease. The Warren infection might have been transmitted to Kittanning and have produced the epidemic there. The coincidence of outbreak in the two places attracts attention, although a local source of infection is more probable. But, besides the bowel trouble, there were

more than 100 cases of typhoid fever in Kittanning. This infection is believed to have been introduced through the medium of the river. Mr. Snow.

This case demonstrates how utterly inefficient may be the effort of those who, misinformed as to the essentials of water filtration, try to safeguard human life. Here was a water purification plant, installed for the purpose of preventing a recurrence of typhoid fever, totally inadequate to perform the service expected of it by the public, but, nevertheless, serving to foster a false sense of security.

In such a case, where the source is always dangerous, the interests of the public health demand competent design and skilled supervision of the construction of the purification works at first, and thereafter, capable management of its operation, and efficient maintenance.

The business of furnishing drinking water to the public is bound to be regulated by laws, passed to be enforced by central administrative power. The courts are beginning to give a different meaning to the words, so frequently appearing in water-works franchises, "pure and wholesome supply." Practical methods have been evolved whereby it is possible now to render water purer than it may be possible to obtain it in a raw state. The consumer is entitled to the kind of article he purchases, that is, a "pure and wholesome supply," and a Pennsylvania court has recently held that primitive methods of water purification, whereby a slightly better water than exists in the stream is furnished to the consumer, is not sufficient as long as that water is prejudicial to the public health.

The Butler epidemic, of the winter of 1903-04, affords a different lesson. At that place the public water supply was adequately filtered by a plant properly designed and operated. The source was from a rolling farming district, yielding turbid waters at times, and subject to possible sewage pollution. The filters had been installed to eliminate all danger and produce a clear water. This they did. The plant was one of the advertised assets of the borough; therefore, when the town woke up one day to the presence of considerable typhoid fever in the community, no one, not excepting even the newspapers (so alert usually to scrutinize critically a public utility plant), seriously suspected the water supply; and, remarkable to relate, not until 1 000 people were stricken and in bed was State aid called for and the true origin of the scourge discovered. The disease did not come in a day, but was cumulative.

The filter plant had undergone repairs just prior to the inception of the epidemic. During this period of repairs—several days—crude creek water was introduced into the street mains. There were several cases of typhoid fever on the water-shed, in a dwelling on the banks of the stream. The dejecta from the patients were

Mr. Snow. thrown out on the surface of the ground, where nothing prevented the poison from being washed into the creek, and hence within a few hours it arrived in the homes of the unsuspecting, confiding and wholly helpless water consumers.

Had the local or State health authorities been made aware of the first outbreak of the disease, or of the original cases on the water-shed, the history of the Butler epidemic might never have been written. But, as it was, 1348 cases were recorded and 111 deaths.

This catastrophe produced one good result, namely, the establishment of the State Bureau of Vital Statistics. At present, physicians are required to send in morbidity reports. A repetition of the Butler case is not possible. That is, a community cannot be gradually attacked by typhoid. The onslaught must be sudden and sufficiently intense to cause the harm at once, because the officers of the local and State health departments are ever on the lookout, and report to the central office the first appearance of any infectious disease.

However, systems of reports can only apprise of danger. The poison may be disseminated through a water-works system in a few hours, and the first infection may take place before knowledge of it is possible. To the initial infection at Scranton should be attributed about all the cases there. Had the disease escaped detection in its early inception, the epidemic would undoubtedly have far exceeded the proportions it assumed, and thus might easily have gone down in history as the most appalling typhoid scourge on record. Thus the early discovery and the shutting off of the infected water in this one instance alone probably saved to the community, besides human life, a money consideration greater than the amount expended annually on records by the State and city Departments of Health.

In another instance, Johnstown, by the prompt report of typhoid on the water-shed, was saved from an epidemic under circumstances otherwise assuring a sweeping disaster. The poison was intercepted and killed, and not a case occurred in the town. Unquestionably, the morbidity reports instituted by the Commissioner of Health will repay to the public the cost of maintenance of the Bureau, and this work has been made necessary in following out the policy of preventing pollution of impounding reservoir and other surface supplies, as far as it is practicable to do so.

The Butler lesson teaches that an efficient filter plant is not an absolute safeguard; that as long as there is poison in the source, the danger of an explosion of disease of a water-borne character exists.

The Plymouth epidemic of 1885 attracted the attention of the world's sanitarians. The case was unique at that time. A town

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nestled at the foot of a mountain, furnished with a pure mountain water coming from an uninhabited water-shed—excepting one dwelling—was suddenly the scene of the terrible scourge of typhoid which numbered 1 104 cases and 114 deaths. The discovery of the origin was, for that day, a masterful work of detection, clear-cut and uncontroverted.

The owner of the single dwelling-house on the water-shed went to Philadelphia, contracted typhoid, came home, and was attended by a physician and nurse who did not know that the little stream at the foot of the bluff, on the edge of which stood the cottage, was the source of Plymouth's drinking water, and so they threw the poisonous stools out on the ground, where the dejecta remained frozen during the cold winter months; but in April, when the thaw and warm rains came, and the ice and snow all disappeared, the typhoid poison, along with everything else, was carried into the creek, and thence some of it found its way through the water pipes and into the town.

This was not the only supply to Plymouth. The Susquehanna River, receiving the sewage from Wilkes-Barre, 3 miles above, was used occasionally for parts of the town. This source was thought to be dangerous because it contained sewage, and suspicion had been directed to it for a long time. The public persisted in attributing the epidemic to the Susquehanna River water, until the proof of the true origin became conclusive. Although Wilkes-Barre's sewage constituted an immediate and always present menace, yet the citizens of Plymouth had not, prior to 1885, suffered from typhoid more than had other communities in the vicinity having sources of water supply which were not from the river. Contrary to the expectations of those interested in this case, came the proof that a constantly sewage-polluted river supply used by people who know the danger in the water, may not be as prejudicial to public health as a mountain supply free from pollution and having but one apparently insignificant menace upon the water-shed.

The disease held on through the summer months. Privy vaults abounded in the borough, also wells in close proximity thereto. People, mostly miners of foreign birth, would not heed the admonition to boil all water, and to disinfect all dejecta. Consequently, the wells were poisoned and the percentage of secondary infection was large.

The general lesson taught was startling and broad. Since one case of the disease imported could pollute the water supply of an entire town sufficiently to produce wholesale sickness and death, the officers of public and private corporations all over the country, were startled at the proposition that no municipality taking drinking water from surface sources is safe.

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The conclusion reached at that time was that the individual in the village or rural district must dispose of his excrement in such a manner as not to pollute, directly or indirectly, any surface or well water.

The remedy was accepted as ideal, and impractical of accomplishment. To-day, with the aid of advanced methods of water and sewage purification, of public hygiene and municipal sanitation, a very much nearer approach to the ideal is practicable than in 1885. To this end the Pennsylvania State Department of Health was reorganized by the law of 1905, and the responsibility for progress in this branch of State medicine was placed in the hands of the Commissioner of Health.

The instances herein cited serve as a foundation for the enunciation of the principle that no unfiltered surface water, in any way likely to be polluted by sewage, is absolutely safe for drinking purposes. The risk attendant on the use of it may be slight. Where the risk is great, the life and health assurance afforded by filtration of the water is demanded as a public safeguard.

Still further, filtration is not an absolute safeguard, more especially when the source is subject to sewage pollution. The interests of the public health demand that sewage pollution of public supplies shall cease. Standards of excellence in the design, construction, and operation of water filter plants are first essentials to guard the public health, but this safeguard should not put a premium on the use of the watercourse as a sewer by some up-stream municipality. On the contrary, the original pollution of the water must be minimized.

A year ago the proper authorities of the three sovereign States—New York, New Jersey and Pennsylvania—met to formulate a policy of co-operation with respect to the sanitary conservation of inter-state streams and their tributaries. It was unanimously agreed that water filters were not alone sufficient, but that both water and sewage purification plants are demanded, in the interests of public health.

The right of eminent domain in Pennsylvania has been taken away from public water companies. It has been decided to be contrary to public policy to permit such companies to acquire thousands of acres of land for protective purposes. Further, it has been observed that purchase and control of large water-sheds does not necessarily prevent pollution.

A certain quantity of sewage is bound to find its way into the waters of most inhabited areas, but the legalizing of a certain amount of pollution of such waters, relying upon filtration to correct the effects thereof, is a dangerous expedient to practice generally. Start with the proposition that, after all is done that may

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be done to keep sewage out of drinking water, the streams draining populous areas will still be unfit to use unless the water be filtered, and, using this as an argument against sewage purification works, grant licenses to towns to discharge sewage into the watercourses, and inevitably the pollutions must exceed the "certain amount."

The popular notion that it is permissible to discharge sewage into a stream which is not thereby made offensive to the sense of sight and smell is far from being dispelled. The local authorities of many towns are honestly dense with respect to this subject. It took an epidemic to teach the 1905 Board of Health of Nanticoke that the excrement of one individual could be transmitted many miles and kill those who drank the poison, although nothing might be visible in the water to indicate the danger. Yet Nanticoke is nearly opposite Plymouth. After the lapse of twenty years, the Plymouth lesson had to be repeated in the same district. It is not from the standpoint of nuisance, but from the standpoint of pathogenic pollution, that the campaign against putting sewage directly or indirectly into the waters of the State is being waged in Pennsylvania.

When the enormity of the crime of defiling water supplies appeals generally to everybody, there will be voluntary reforms. Meantime, the administration of law is a very pertinent matter. There is no public work of more importance to health than water purification and sewage disposal. Pennsylvania provides for central supervision of these utilities. No water-works or sewerage system can be legally extended or installed unless plans therefor have been submitted to and approved by the Commissioner of Health. Respecting the discharge of sewage, by a municipality, into any stream or body of water, the unanimous agreement of the Governor, Attorney-General, and Commissioner of Health is required. A penalty of $50 is provided for every day that a municipality pollutes illegally any of the waters of the State.

Dr. Charles B. Penrose, of Philadelphia, conceived the new State health laws, prepared the bills, and labored assiduously for their enactment. They are a worthy monument to a worthy man. The Honorable Samuel G. Dixon, who, as first Commissioner of Health, has had the task of organizing the new Department to put his conceptions of State medicine into operation, has inaugurated a policy which is bound to reduce water-borne diseases to a very large extent.

Every minor source of pollution on the water-sheds is to receive attention, and all menaces are to be permanently abated. Patrols by private and municipal corporations are to be required. The owner of each estate must cease to be careless about the disposal of sewage. Such disposal must be accomplished in a way unharm-

Mr. Snow. ful to others. Ordinary farm operations cannot be interfered with, but the effort is to confine pathogenic material within bounds. A health officer has been assigned to every municipality, to investigate, report, and execute orders.

Major pollutions, such as municipal sewerage systems, require more consideration. Often, the problem is one of finance. Slowly but surely the sewage of towns will cease to be discharged, untreated, into the waters of the State. First-class operation and maintenance of plants which have been constructed under State approval will be required. The necessity for State supervision is recognized, in fact, demanded. Without it, the "certain amount" of pollution of surface water supplies would be a large and dangerous amount, and the moneys, therefore, expended in the construction of sewage disposal works would be lost to a considerable extent.

Mr. Clarke. D. D. CLARKE, M. AM. SOC. C. E. (by letter).—That the purity of the water supply of any city is a matter of vital importance is so generally recognized that it seems almost superfluous even to state the fact; but, when it comes to the question as to the best method of securing and maintaining the purity of the supply, there is a diversity of opinion. The writer holds that it is better to secure such a supply as shall be of unquestioned purity, rather than attempt the purification of waters known to be contaminated in the slightest degree; but it is recognized that the financial question involved is often a controlling factor, making necessary the adoption of methods which otherwise would not be approved.

As an illustration of what it is possible to accomplish, at least in the more recently settled portions of the continent, the writer would cite the case of Portland, Oregon, a city of 150 000 inhabitants, which secures an abundant supply of pure water from an absolutely uninhabited water-shed situated on the western slope of the Cascade Mountains from 30 to 50 miles distant from the city.

The advantage of this supply, as a factor in the life and growth of the city, can hardly be over-estimated, and it is safe to say that it is with a growing appreciation of its value that the residents of Portland regard everything that pertains to it or affects it in any way; and hence they are fast coming to feel in a measure justified in felicitating themselves upon their good fortune in being permitted to dwell in a city possessing such an abundant supply of pure water.

It is now nearly twenty-five years since the question of municipal ownership began to be discussed, and surveys were made looking toward securing a water supply for the city from a mountain stream.

In 1886 a citizen's committee, numbering fifteen of the substantial business men, was empowered by the State Legislature to

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purchase or construct and operate water-works for the supply of the city. In the following year the Water Committee purchased the plant of the old Portland Water Company, which had been supplying the city with water from the Willamette River by pumps installed at a point on the river bank about 6 miles above the city; these works they continued to operate until the Bull Run gravity system was completed in 1895.

The surveys for the gravity system, made under the direction of the late Isaac W. Smith, M. Am. Soc. C. E., who also constructed the works, developed the fact that the most available and altogether satisfactory source of supply was to be found in the water-shed of Bull Run River, in the foothills of the Cascade Mountains, eastward from Portland. The point finally selected for the intake is situated on the Bull Run River, about 5 miles from its junction with the Sandy, a tributary of the Columbia, and 30 miles from Portland, the elevation of the intake being 720 ft. above low water in the Willamette River. This point is in the edge of the foothills but well above the general level of the valley, while thence eastward the ground rises rapidly to the summit of the Cascade Range.

The entire western slope of the range is covered with a dense forest, and the work of exploration is difficult at all times. Little was known regarding the water-shed of the Bull Run prior to the time of making the surveys for the city. From the maps on file in the office of the United States Surveyor-General, the approximate area of the water-shed was known to be about 140 sq. miles. The existence of a lake near the summit of the range was also known, and but little other information was available concerning the region east of the point selected for the intake to the conduit. It should be stated, however, that prior to the selection of this stream, as the source of supply for the city, the main stream and the lake were explored by engineers in the employ of the Committee, and it was thereby determined that the flow of the stream was ample to provide for the future needs of the city.

In 1891 additional explorations were made by Mr. Frank T. Dodge, Superintendent of the Water Department, and, as a result of his recommendations, the Water Committee made formal application to the Department of the Interior for the withdrawal of the entire region as a Government reserve. This withdrawal was accomplished on June 17th, 1892; under the name of the Bull Run Forest Reserve, covering an area of 222 sq. miles and entirely surrounding the water-shed of the main Bull Run River.

Regarding this reserve the following statement is made:

"The United States will not sell any land in this reserve, nor permit timber to be removed from it, nor allow sheep or cattle to

Mr. Clarke. be pastured thereon. So long as the laws governing these matters remain unchanged, the water supply of Portland cannot be injured, providing the law to prevent forest fires on the public domain is properly enforced. The forest shades the snow which every winter covers the land deeply, and retards its melting; the undergrowth protects the soil and prevents it from being washed into the streams. The result is that no settling reservoir is needed, the water is always clear as crystal and free from sediment even during the greatest freshets. It is so cool that it does not need ice to make it palatable."

At the time the Bull Run reserve was established there were within its borders but few tracts claimed by private parties, and these were mostly held as timber claims by non-resident owners. Only two or three of the claimants ever made any attempt to build houses or make any permanent improvements in the way of clearing and cultivating the land. In a very few years the Water Committee succeeded in acquiring control of all improved claims, and has since continued the work of extinguishing private title to all lands within the reserve. At the present time the entire reserve above the intake is absolutely uninhabited.

From the beginning it has been realized that the greatest danger which threatens the water supply is that due to forest fires, which are very destructive during the summer and early autumn of especially dry seasons, these fires being usually due to the carelessness of hunters, fishermen and campers within the reserve or along its borders. In order that the danger from this source may be reduced to a minimum, the reserve is patrolled by forest rangers employed by the Government, and, in addition, extra patrolmen are frequently employed and paid by the Water Department, in order that a thorough inspection and isolation of the district may be maintained. This work is in charge of the officials of the United States Forestry service. In furtherance of this protection work a special Act of Congress, passed April 28th, 1904, prohibits all unauthorized persons from entering the reserve, all trespassers being liable to a fine not exceeding $500.

The low-water flow of Bull Run River is estimated to be from 65 000 000 to 70 000 000 gal. per day. If a larger quantity should ever be required, it would be a question of storage in Bull Run Lake or elsewhere. Rainfall observations, at the head-works, at the western border of the reserve, show a yearly precipitation of about 70 in., while, at the higher or eastern portions of the reserve, it is undoubtedly much more. It will thus be seen that the average run-off from the rocky and precipitous Bull Run water-shed, of 140 sq. miles, must largely exceed any probable requirements. It is estimated that Bull Run Lake alone will afford ample storage for many years to come. By a comparatively short tunnel, the lake

could be drawn upon so as to supply an extra 100 000 000 gal. per day for the possible 60-day period when the stream is at its lowest stage. Mr. Clarke.

By special Act of the State Legislature, passed in 1906, the entire flow of Bull Run River is secured for the exclusive use of the City of Portland.

The following is an analysis of a sample of Bull Run water taken from the stream after a heavy rain:

Total Fixed Ingredients.

"2.7 parts in 100 000 parts by weight, or 1.89 grains per imperial gallon (of 10 pounds avoirdupois) consisting of:

	Parts in 100 000.	Grains per gallon.
"Silica	0.56	0.392
Oxides of iron and aluminum.	0.08	0.056
Calcium carbonate	0.39	0.273
Magnesium carbonate	0.27	0.189
Chlorides, sulphates and Carbonates of alkali	0.40	0.280
Organic matter	1.00	0.700
Total	2.70	1.890

"The carbonates of lime and magnesia are in the form of soluble bicarbonates. The organic matter is mostly in the form of suspended vegetable substances and partly insoluble products of their decomposition. Microscopic examination of the sediment, and chemical tests of the water show the absence of deleterious organic matter. Only traces of ammonia were found, while nitrates and nitrites could not be detected, showing absence of nitrogenous organic matter. To sum up, the water ranks among the best on record for domestic use."

GEORGE A. SOPER, M. AM. SOC. C. E. (by letter).—It is by no means clear what sort of discussion was desired by the framers of this question. Its wording suggests that, in order to have clean water, we must either build filtration plants or purchase the land through which the water flows. This, of course, is not true. Mr. Soper.

In the average case, people using impounded supplies need not feel that they are driven upon either horn of this dilemma—certainly not to the purchase of whole water-sheds. This is at once the most expensive, least scientific, and most impracticable way to proceed in order to protect a water supply against pollution. For example, it would cost New York City about $58 000 000 to buy the drainage area of its new water supply, provided it could be had at the average rate of $100 per acre; and mere ownership is by no means an insurance against pollution.

The question suggests that pollution may perhaps be tolerated if only filtration is used. This is utterly wrong. It is wrong in

Mr. Soper. principle and not justified in practice. Filtration is a cure, and an excellent cure, as cures go, but it is not an infallible safeguard. Deliberately to allow filth to pollute a water supply with the idea that the water will eventually be cleaned by filtration shows a beautiful trust in filters and a greater confidence in the men who run them; but it is not good sanitary engineering. It has been well said that what we need in water is not repentance but innocence, and when it is possible to keep water pure this should be done by all means.

The extent to which water supplies can be protected against pollution depends upon a number of circumstances, but chiefly upon the amount of attention which engineers and others interested in pure water are willing to give to the subject. If waterworks people would give an amount of attention to regulating the drainage, inspecting the streams, and superintending the disposal of harmful matters on the water-shed commensurate with the time and money which they give to handling the water after they get it, nearly all danger from impounded supplies could be avoided.

Protection means a number of things which the public looks to engineers to understand, but which engineers frequently consider can be understood only by medical men; but physicians, as a rule, are not competent to handle sanitary matters. It is time that engineers accepted the responsibility, and undertook to deal with these subjects themselves.

The sanitary protection of a drainage area means, first, knowledge of the conditions where permanent and accidental defilement may take place; second, the careful design of measures to protect the water against these danger spots; third, adequate provision of law to carry out the measures; fourth, a settled intention to protect the water.

If the purpose exists, difficulties respecting the other requirements will disappear. Experience shows that filth can be kept out of water, if only there is a determination to keep it out.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

FOUNDATIONS.

An Informal Discussion at the Annual Convention, July 10th, 1907.*

SUBJECT FOR DISCUSSION:

"(*a*) What is the best system of construction for foundations of heavy structures on ground such as that of the City of Mexico, which is an alluvial deposit about 300 ft. in depth, and similar in character to that at New Orleans?

"(*b*) Will iron or steel used in foundations, independently or in combination with other materials, last indefinitely when in direct or indirect contact with water?

"(*c*) Will the strength and durability of concrete in foundations be affected if before setting there is: (1) an excess of water; (2) lack of compression; (3) too rapid desiccation?"

BY MESSRS. JOHN F. O'ROURKE AND J. A. L. WADDELL.

Mr. O'Rourke.

JOHN F. O'ROURKE, M. AM. SOC. C. E.—In the three questions submitted in connection with "Foundations," the first calls for the design of systems of construction applicable to the foundation of heavy structural work in the City of Mexico, the ground being an alluvial deposit, about 300 ft. in depth, similar in character to that at New Orleans, and taking into account the supporting power of the more or less unreliable material upon which the structure must be carried; while the other questions relate to the durability or strength of the materials in the foundation structure itself, and the manner in which they are placed, without reference to the character of the material upon which the structure is carried.

*Further discussion, had at the Convention, will be published subsequently, and additional written discussions are invited.

Mr. O'Rourke.

In regard to the first question, assuming that the material is as stated, namely, alluvial deposit having no very great bearing ability, one can approach it from a more general point of view than the question itself suggests. Every railroad engineer has had more or less to do with the carrying of structures or embankments upon swamps and other soft ground, and the ways by which this has been accomplished successfully are so numerous, and oftentimes so simple and well known, that its solution, with regard to carrying heavy structures in the City of Mexico, involves but another form of a very old problem.

It must be borne in mind that soft ground possesses varying powers of resistance to pressure, dependent very largely upon the degree with which it is confined. There are two ways in which the best results are obtained. One is to place the foundations at such a depth below the surface that the surrounding superimposed weight of the material itself prevents the ground from rising; and the other is by the use of one or another form of column to transfer the weight, through the friction on its sides, to the underlying material; enough surface to be brought into such contact to distribute the weight and reduce the stress to that which the material can bear without further movement.

It is not necessary to go into lengthy discussion of either system, since both are well known. The writer has built culverts, and even heavy bridge piers and abutments, upon material into which a man would sink if he attempted to stand upon it, by simply distributing the weight over an area which acted as a whole, because the structure was sufficiently strong to act as a unit in applying the pressure. No formula or rule seems to be applicable by which this area can be fixed, nor can the united resistance which soft ground offers under such conditions be always accounted for, but it is known by experience that material little different from mud will sustain pressure up to 1 ton per sq. ft. after the initial settlement has taken place, when the area involved is considerable and the loading has been uniformly applied over the whole surface. The same is true of the column system, of which the most familiar example is the ordinary wooden pile. It is a common experience, in building trestles across swamps and marshes, to find that a pile which can hardly sustain its own weight when driving has ceased, will, in a few days, take such a "set" that several heavy blows of the pile-driver hammer are necessary to start it again, and when started it will drive about as easily as before, until the harder material is reached; the fact being, however, that given a reasonable penetration in the soft material, the subsequent stability of the pile is not increased very much by its support upon solid bottom. The writer calls to mind, in particular, the case of the foundation

piles in the falsework of the Poughkeepsie Bridge, where piles were driven 100 ft. below the surface of the water into 60 ft. of silt, and were loaded with from 10 to 20 tons each during the erection of the fixed span, and in which no settlement was noticed during the erection of that span. When the first fixed span was completed, the falsework was taken down, and the piles were pulled out and used again in the erection of the second fixed span, the interesting fact developing that a dozen heavy blows of a 6 000-lb. hammer were necessary before a pile could be started, after which it drove easily and was then readily pulled out. Mr. O'Rourke.

It is clear that either of these methods may be used in providing heavy foundations in the City of Mexico, provided nothing in the ground itself would cause the decay of the material used. It is the writer's experience that wood, driven or placed in clay, is as completely preserved as though immersed in water, and, time and again in the construction of foundations in the lower part of New York City, he has removed timber—mud sills and stringers—which had been placed above the water level, but in clay, more than 100 years before, and has always found them in good preservation, where such conditions existed.

As the question of materials enters largely into the choice of the system to be used, if suitable wooden piles are not available, concrete or steel could be used, the choice resting on economic rather than engineering considerations. This is true of the "distributed pressure" system, also, using the three materials separately, or in combination, as may be found most economical or substantial for each case.

Iron and steel used in foundations, apart from conditions where electrolysis may occur, last indefinitely when in direct or indirect contact with water, provided the water remains unchanged. The reason for this is obvious. Water attacks iron or steel on account of the oxygen it contains, and, if this is a proportionately small quantity, the amount of oxygen contained in wet concrete or ground is negligible, and, having once been exhausted, the metal remains unharmed and protected.

The writer has seen many cases where immersion in standing water has been a matter of years, and in every case the effect upon the metal has been no greater than if it had stood for the same length of time in linseed oil. In one case bolts on the inside of cast-iron cylinders, filled with concrete, were exposed to the salt water in the Harlem River for more than 30 years, and when removed were found to be without rust. In another case a pipe was immersed for ten years in an Artesian well, the water in which had not been pumped for 10 or 15 years, and no corrosion of this inside pipe had taken place, the scale was still as fresh as when the pipe

Mr. O'Rourke. was new, and the tool marks of the pipe-coupling apparatus were still perfectly fresh.

Similar results came under the writer's observation in reference to the condition of rods and nails found in wooden foundations where the surrounding material was impervious to air, and in one case which came under his observation, at the time of the removal of the old elevated railway columns in Greenwich Street, New York City, prior to making way for the new structure in 1878, the bottom part of these columns and the bolts in the masonry were found intact, the corrosion gradually increasing until near the surface, where the material was almost entirely destroyed by rust. This experience with both wood and iron, where the renewal of the oxygen in the surrounding water was prevented, has been uniformly that of finding the material perfectly preserved, so that, in the writer's practice, he does not hesitate to advise the use of either material under conditions where a fresh supply of oxygen is excluded. The casing of concrete, in his belief, is an absolute protection against any oxygen penetrating to the surrounding water, and the uniform practice in foundation work in New York City, where both materials are used in combination, is to pay no attention to water-proofing as a preservation, but depend on the concrete to preserve the iron, which it does in the manner stated. There are exceptions to this, of course, but, generally speaking, where the water-proofing is put underneath the steel, it is for reasons connected with the water-proofing itself, more than from any intention to protect the steel in that way. As a matter of fact, water in one form or another is always a possibility, but conditions can be insured which will prevent its being changed, which is the great desideratum.

In answering the third question, it is the writer's belief that concrete should always be made so wet that it will not permit of ramming, but that, after the concrete has been put in place, a certain amount of spading, or "packing back," in the case of the form, so as to give a smooth finish, is all that is necessary in order to produce the most compact and durable concrete. As to rapid desiccation, there is no doubt that if concrete is dried out, or has not had sufficient water to permit of the chemical action or "set" being a finished chemical action, the concrete will be poor, or even worthless. It is not likely to occur, however, under most conditions, even where fresh concrete is allowed to set in the sun, but it has come under the writer's observation many times, in placing concrete under compressed air, that the air which escapes through the concrete in passing out of the air-chamber of a caisson, is most likely to create veins through the concrete from which the water evaporates before the concrete has had an opportunity to set, leaving that part of the

concrete in a condition which is changed very little from that of the dry materials before the concrete was mixed. Mr. O'Rourke.

In specifications, the writer would advise the entire elimination of the requirement for ramming in beds, and that the concrete should have sufficient water to enable it to puddle itself, with such handling and manipulation as are always incidental to placing it, the only exception being arch work and form work, where ramming may be necessary in order to drive the concrete into places which otherwise it might not fill properly—the ramming in this case being for the purpose of filling the mould, not for compacting the material. As to conditions where the rapid desiccation might threaten it, this should be provided against wherever possible. There is no doubt that wherever this occurs the quality of the concrete is injured and sometimes destroyed.

The writer regrets very much that owing to important business he is prevented from attending the Convention and presenting his views in person, and begs the members kindly to accept the foregoing as the best he can do under the circumstances to open this very important discussion. He will be greatly pleased to submit a further discussion of this matter before the subject is closed, and answer, as well as he may, any questions that may be asked during the discussion.

J. A. L. WADDELL, M. AM. SOC. C. E. (by letter).—Early in 1900, the writer made an investigation of the subject of "Foundations for Important Buildings in the City of Mexico," in the expectation that he would be retained to design the foundations for a large public building then under contemplation for that city. For this purpose he evolved a new type of substructure for buildings to meet the special conditions existing there. Being disappointed in his expectation, and not wishing to lose the credit for the conception of the design, he prepared a paper for the *Mexican Herald* and had it translated into Spanish for one of the other leading papers of Mexico City. Both the original and the translation were published in March, 1900. The paper caused some little discussion in the local press, but, as yet, no foundations of the type proposed have been built. Some of the Mexican engineers stated that they did not like the design, but could give no specific objection to it except its novelty. Mr. Waddell.

For three hundred years Mexican architects and engineers have been overloading the foundations of buildings in Mexico City, notwithstanding the fact that the number of stories is generally limited to two or three. The writer's idea was to disturb the soil as little as practicable, and to load it only to the extent of 1 000, or, perhaps, 1 200 lb. per sq. ft. For isolated buildings, he advised cantilevering the base out on all four sides, and for buildings in

Mr. Waddell. blocks, cantilevering in front and rear. His method of construction can best be explained by the following quotation from his paper in the *Mexican Herald:*

"Bad as is the soil of the City of Mexico (and it would be difficult to find anything much worse for foundations), there is no reason whatsoever for failure of any kind in buildings that are properly designed to meet the conditions of the soil and those due to earthquakes. This may seem to be a rather sweeping statement, but the writer does not hesitate to make it, and to back it with his professional reputation.

"In order, however, to obtain immunity from the aforesaid dangerous conditions, it will be necessary for Mexican architects to modify many of their old methods of building construction, and to not only adopt the latest ideas but also go a step farther and accept some new ones, evolved especially to meet the peculiar conditions existing in this city.

"As is well known, the City of Mexico is located on the bed of an ancient lake; and by digging down but little more than a metre, water level is reached. The characteristics of the soil vary somewhat in different parts of the city; but, in general, it may be stated that there are some two metres of a soft, sandy clay overlying a stratum of so-called tepetate, which is really little else than a more solid layer of the superimposed earth, and not true tepetate at all. This stratum is on the average less than a metre in thickness, and below it lies an extremely soft mud of indefinite depth.

"Such being the case, the following axiomatic conclusions may be drawn:

"1st. Piling is not applicable for consolidating the ground, because there is no firm bottom for the piles to reach, and because the soil beneath the hard stratum is of too fluid a nature to offer any material resistance by side friction.

"2d. The hard layer should under no conditions be disturbed, and the total load that it sustains should be distributed over it as uniformly as possible.

"3d. The more of the existing soil that is left undisturbed over the hard layer, the more uniform will be the distribution of the load over the latter.

"4th. The less material used in the foundations of a building, the smaller will be the weight of the said foundations, and the greater will be the permissible load from superstructure that can be adopted.

"The general opinion in Mexico appears to be that a total superimposed load of one thousand (1 000) lbs. per square foot is about as high as can be considered safe for the soil of the city; but, if the writer had any important building to design, he would certainly first make a number of tests of the actual bearing capacity of the soil, and would be governed by the results thereof in proportioning the entire structure.

"As in any area of any magnitude, the soil overlying the hard stratum is much softer in some places than in others, it is impracticable to adopt the customary American method of so dis-

tributing concentrated, isolated loads as to insure a uniform settlement of the entire building; consequently, if this method be tried, it will certainly result in failure. Mr. Waddell.

"Again, the haphazard method of placing beneath the walls masses of concrete containing steel rails will not suffice; because such masses will not have the necessary strength and rigidity to prevent unequal settlement and the consequent cracking of the walls.

"With very soft soils of uncertain and unequal bearing power, there is but one method of preparing a foundation for a large, heavy building, that will ensure the structure against failure by cracking, and that is to support the superstructure upon a continuous platform of steel encased in enough concrete to preserve it effectively against oxidation, the said platform having sufficient strength and rigidity to bear without appreciable distortion all inequalities of loading from above, due to variations in amount and position of the live or moving loads, and to take care of the prejudicial effects of the unequal bearing capacity of the soil at different parts of the foundation. Or, in other words, the building should be floated on the soft soil by making it into a box with a rigid, continuous bottom.

"If the building be an isolated one in reference to other buildings, the platform can be extended beyond the walls so as to provide a much greater bearing area, and thus permit the adoption of an increased number of stories; but, if the said building be one of a block of houses, the base can be cantilevered out only into the street or alley (if there be one); consequently the number of stories will then be limited by the allowable maximum pressure on the soil.

"This is the type of foundation evolved by the writer specially for large and heavy buildings in the City of Mexico. It will certainly (if properly detailed) prevent all injury to the buildings from unequal loading and unequal supporting capacity of soil, and will aid materially, if not perfectly, masonry walls to resist earthquake shocks. However, to ensure the walls against damage by the latter, the framework of the building should be of steel construction; but of this, more anon.

"The details of the writer's proposed type of foundation are as follows:

"1st. If the surface of the ground be very soft or irregular excavate to an average depth of a couple of feet the entire area to be occupied by the platform, then roll with heavy rollers the bottom of the pit thus formed until the bed is firm, filling in with a mixture of clay and gravel any inequalities caused by the rollers traversing earth of varying softness, and keeping the rolled material slightly damp by sprinkling it with water from a cart.

"Next put in a thin layer of clay and gravel, dampen it, and roll it until it is compacted thoroughly, then another similar layer and another until the surface of the base is brought up to or a little above the average original level of the ground.

"2d. Lay out the steel work of the base so that the main girders come under the lines of the walls and columns, making them all of

Mr. Waddell. the same depth so that, by placing splice plates above and below at the intersections, all girders will be continuous from end to end.

"The proportioning and detailing of these girders constitute an engineering problem of no mean order, as it is these girders alone that must take care of all inequalities of both loading and bearing resistance, unless steel superstructure be adopted, in which case sway diagonals embedded in the walls will aid materially in resisting the bending caused by these inequalities, and will thus permit of a reduction in the amount of metal required in the base.

"3d. Next, run primary girders at convenient distances apart, parallel to one set of the main girders and riveting into the other set. These girders will carry no load except the local upward pressure from the soil pertaining to the small areas that they dominate.

"In section these primary girders can be either rolled I-beams or small built girders.

"Next, run small secondary girders into and at right angles to the primary girders, thus dividing the total area into small rectangles that are approximately squares. These secondary girders should be small rolled I-beams.

"Finally, run tertiary girders of still smaller I-beams into and at right angles to the secondary girders.

"The upper surfaces of the main, primary, secondary and tertiary girders should be approximately at the same level.

"It is almost unnecessary to state that, between the ends of the main girders which are cantilevered beyond the exterior walls, there are to be primary, secondary, and tertiary girders like those in the space bounded by the said exterior walls.

"4th. If there are to be steel columns in the superstructure, these should be located directly above the intersections of the main girders of the base, and should be so designed as to rivet into the latter and be braced thereto substantially by steel brackets or knees, which will lie within the walls.

"5th. The main and primary girders are to be sunk into the earth by excavating trenches therein, but the secondary and tertiary girders are to lie above the surface of the ground.

"There is to be a single layer of concrete covering the whole area and enclosing all the secondary and tertiary girders; and the portions of the primary and main girders which project below this are to be encased in the concrete with which the trenches in the earth are filled.

"By this design the weight of concrete in the base is reduced to a minimum, thus leaving the greatest possible portion of the permissible earth load for sustaining the weight of the superstructure and its live load.

"6th. This design reduces the functions of the concrete to merely two, viz., to act as a protecting covering for the steel, and to carry the upward pressure of the earth to the secondary and tertiary girders.

"7th. The detailing of the metal-work in the base, the location of girders and the splices in same, and the *modus operandi* of erecting the metal and placing it in the concrete are engineering details

of a purely technical character, so that it would be out of place to treat of them in a general paper like this, written, as it is, as much for the public as for the architects and engineers of the City of Mexico." Mr. Waddell.

The writer recognizes the fact that girders of reinforced concrete might be used to replace the steel girders in his foundation design, but, for the same strength and rigidity, their weight would be much greater, and, consequently, their use would not be so advantageous for meeting the extreme conditions of weakness inherent in the soil of the City of Mexico. It is possible that the tertiary, and perhaps also the secondary, girders, might be replaced advantageously by reinforced concrete, but, in the writer's opinion, this is doubtful.

In any case, the thickness of the made ground should be a little greater than the vertical distance from the top of the concrete platform to the bottom of the concrete in the trenches excavated for the main girders. The raising of the platform 2 or 3 ft. above the surface of the surrounding soil would be beneficial in more ways than one, because it would provide for a possible settlement of the foundation as a whole, and would prevent water, during rainstorms, from flooding the ground floor.

The *modus operandi* of constructing the foundations is as follows:

After the made ground is finished and the entire metalwork for the foundation is delivered, the trenches for the main and primary girders should be dug to the required depths, provision being made for 6 in. of concrete below the main girders. Then the entire metalwork should be assembled and riveted in true position horizontally, but at an elevation somewhat above its final position. A large force of men for mixing and placing the concrete should be provided in order that the concrete work over the entire area may be carried on simultaneously, thus avoiding dry surfaces in the mass, and insuring that the latter shall be truly monolithic. In concreting, the first step is to place 8 or 9 in. of soft concrete in the bottoms of the trenches in the shortest possible time, then lower quickly the entire platform to its final elevation, and fill the remainder of the trenches with concrete to the level of the made ground. Then cover the latter throughout with well-rammed concrete up to 2 in. above the top of the highest metalwork. By having a large force of men, the whole of the concrete work could be completed before setting takes place. Of course, the upper surface of the platform should be dressed off smooth with mortar before the concrete has dried.

In order to reduce the load on the foundations to the very lowest possible limit, it might prove advisable to adopt nickel-steel

Mr. Waddell

for the main girders, and, in certain extreme cases, also for the primary girders. As all loads on the girders are practically static, it would be permissible to strain the metal to one-half of its elastic limit. The writer recognizes that the adoption of such a high intensity of working stress would involve cracks in the encasing concrete, but, in his opinion, these cracks would be so small as not to permit of moisture reaching the metal. Moreover, the raising of the basement platform 2 or 3 ft. above the level of the surrounding soil would prevent water from remaining for any length of time as high as the elevation of the lowest part of the metalwork.

It is to be hoped that the action of this Society, in discussing at its meeting in the City of Mexico the question of foundations for heavy buildings in that city, will induce Mexican engineers and architects to give the subject due and thorough consideration, and thus effect a radical change in foundation designing which has been sadly needed in Mexico City during the last three centuries.

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PAVEMENTS.

An Informal Discussion at the Annual Convention, July 10th, 1907.*

SUBJECT FOR DISCUSSION:

"Will the paving materials of the present be used in the construction of the pavements of the future?"

BY MESSRS. GEORGE W. TILLSON, J. H. HAYLOW AND CLIFFORD RICHARDSON.

Mr. Tillson.

GEORGE W. TILLSON, M. AM. SOC. C. E.—When one remembers that thirty years ago there was not a mile of the standard pavements of to-day in existence in America, is it strange that the thinking engineer wonders what new developments in street pavements will take place during the next thirty years? Will the principal changes be in the materials used, in the methods of using them, or both?

In order to speak with any intelligence of the future of any industry, it is always necessary to become conversant with its past history as well as the present conditions.

At the risk, therefore, of repeating some things which the speaker has said in other discussions of the pavement question, he will review briefly some of the conditions and experiences which have led up to the adoption of the pavements now in use.

Paris and London did not have street pavements until they had become cities of 200 000 and 100 000 inhabitants, respectively. This might seem strange unless it were understood that wheeled vehicles did not come into general use until the sixteenth century, the

*Further discussion, had at the Convention, will be published subsequently, and additional written discussions are invited.

Mr. Tillson. transportation of merchandise in the interior being carried on by pack-horses and other beasts of burden.

The first pavements were built of cobble stones and of irregularly shaped stones. These latter were gradually improved in shape until finally they developed into the large, flat stones now in quite general use in Italian cities. They did not, however, resist heavy traffic successfully. Pavements of the above character have been disclosed in the excavations recently made in the streets of Pompeii. These must have been laid nearly two thousand years ago. Their construction, with large crossing stones at the intersections, plainly demonstrates that wheeled vehicles were used very little, if at all.

Pavements, however, improved slowly, and in 1826 a London engineer, after investigation on the Continent, reported that the best pavements he saw were those with specially prepared wheel tracks, 3 ft. in width, and 4 ft. apart, the space between being paved with small stones. He said, also, that these pavements would be too expensive for London.

As cities became more wealthy, and traffic increased, better streets were demanded, and the rough block was better made, until the Belgian block of Europe and the oblong granite block of the present were evolved.

This would seem to state briefly the development of the industrial pavement.

Pavements of the above materials, however, are not satisfactory for modern cities. Pavements, now, must not only be durable but noiseless and easily cleaned, in order to be at all satisfactory. A few years ago these might have been considered æsthetic qualities, but now they are necessary. Attempts to satisfy these demands have produced the asphalt and wood block pavements.

An important quality of a pavement is that it shall not be slippery, and the lack of this quality has prevented many a material from being used successfully.

Time will not permit the discussion of the different experiments that have been made with such materials as iron, hay, glass, etc., or why they failed; suffice it to say that the standard pavements of to-day are constructed of stone, brick, bitumen, and wood.

The perfect pavement has never been constructed. The speaker has no hesitation in stating that municipal engineers in charge of pavements have failed to solve satisfactorily the problem presented to them. In most constructive work, any result can be obtained if sufficient funds are available. An architect can build any kind of a residence desired; a bridge engineer can erect a bridge that will satisfy perfectly the requirements of traffic, and be pleasing to the eye; but a pavement engineer cannot lay a pavement that will be entirely satisfactory; and, in this statement, durability is not con-

sidered, but only the public requirements. A pavement is laid primarily to sustain traffic, but, no matter how well it does this, it is not a complete success unless it can be cleaned e sily and is neither slippery nor noisy. What pavement will satisfy the above four requirements? But, to go further. Pavements are laid for the convenience of the public, and should an engineer be fortunate enough to construct a pavement that would fill these conditions, if it were of such a character that it would wear out quickly and require constant repairs, it would be a failure. Any interruption of the traffic of a street interferes seriously with business, and often causes material financial loss; so that it can be said that the perfect pavement must, not only have the properties named above, but must be so durable that its necessary repairs will not obstruct traffic seriously. Mr. Tillson.

The proposition then is, can the perfect pavement be constructed or approximated with the materials now prevailing, or must new materials be used? When it is known that the great improvements in pavements that have been made in the last thirty years have been mainly in the use of many new materials, the latter might be expected; but the speaker believes that the engineer himself is at fault, that he has not made the most of his opportunities, and that he has not made sufficient study of the needs and wants of each individual street. He appreciates fully, too, that, very many times, reasons other than engineering determine the character of the particular material. But he believes that too often an asphalt pavement is considered simply as an asphalt pavement, a wood pavement as only a wood pavement, without any serious consideration as to just how it should be laid to meet the requirements of any particular location. Specifications are too general. By a little study the cost of a pavement on one street may be reduced sufficiently to permit improvements to be made to a similar pavement on another and more exacting street, and the result may be two pavements which are relatively equal.

One great defect often found is in the foundations. It is generally accepted that in any work of construction the foundation is the important part. This is so well understood that it needs no elaboration. And yet, in pavement construction, it is constantly violated.

In order to get the greatest durability from a block pavement, the traffic should be applied directly to the tops of the blocks. And, in the proportion that this practice is varied from, to just such an extent is the life of the block reduced. If this needs confirmation, examine a trench which has been roughly repaved, and note the wear on the individual blocks.

It can be laid down then, as an inviolable rule, that, no matter

Mr. Tillson. what the character of the pavement may be, it must always be laid on a firm foundation.

It is now proper to discuss the different pavements in use, in order to learn, if possible, how they can be improved.

It is admitted by all that the first-class stone streets of Europe are better than streets of a similar class in America. The difference is principally in the blocks themselves. They are better dressed and more uniform in size. If more attention were given to the making of the granite blocks in America, the pavements would be less noisy and much more durable; and, as the noise is one of the greatest objections to stone pavements, anything that will reduce it is an important improvement. Granite as it is used becomes smooth and consequently slippery. This can be helped by making the blocks smaller; and, if they are well dressed, they can be set closely together, and so make it practicable to fill the joints with a bituminous paving composition alone, without gravel. This would also greatly reduce the noise. If automobile trucks come into general use, as they now bid fair to, the question of noise, now so important, will gradually grow less, and a pavement of well-dressed granite blocks, from 3 to 3½ in. thick, laid close together, with joints filled with some bituminous or similar mixture, will be very satisfactory for many streets.

One of the greatest objections to a good brick pavement is that it is noisy. It is often difficult, however, to tell by preliminary tests how satisfactory an unknown brick will be in a pavement, the product of different kilns often requiring different tests to enable the engineer to determine which is the best specimen. As brick is a material which is so available for many interior cities, and has given such excellent results, as far as durability is concerned, any practical change in methods which will reduce the noise will be of great benefit. As the speaker has had a limited experience with this material, he feels somewhat diffident about making suggestions, but thinks that, in addition to having the joints filled with a yielding substance, if the bricks themselves could be bedded in the same material, without too great an expense, the noise from the traffic would be materially deadened.

The construction of coal-tar pavements in Washington, some thirty or more years ago, and their development into the bituminous pavements of to-day, has made a greater change in street conditions than anything that has occurred since streets began to be improved. They filled several long-felt wants, as they were smooth, comparatively noiseless, and easily cleaned. Thousands of miles of such pavements have been laid since 1877, and their popularity is still increasing. The pavement mixture is artificial, and consequently is subject to considerable variation. There is no class

of pavements that taxes the ingenuity of the expert as much as the bituminous ones. When these pavements were introduced they were constructed according to the specifications of the contractor, who guaranteed them for a term of years. This practice has been kept up, to a certain extent. Few city officials hold their positions long enough, or have sufficient facilities for studying such subjects thoroughly enough, to decide arbitrarily on asphalt specifications. The general public looks askance at specifications prepared by contractors, but what can be done? The only thing is for the official to have sufficient knowledge to determine whether the conditions are drawn in the interest of the contractor or the city. Few engineers of the country are qualified to design asphalt pavements for different conditions. That is one reason why such pavements have so often failed. They were not properly designed for their work. The one great defect has been in the foundation, but the wearing surface is of great importance. An asphalt pavement is like a carpet laid upon a floor. Both the carpet and the floor must be good, or the result is bad; a failure in either causes a failure in both. Mr. Tillson.

The three forms of bituminous pavements now in use are sheet asphalt, asphalt block, and the bitulithic. Sheet asphalt pavements made the reputation of such pavements. The main objections to them are that they are slippery, and will not stand heavy traffic. Both these objections can be helped, if not overcome, by proper design. Clifford Richardson, Assoc. Am. Soc. C. E., in a paper recently read before the Society of Chemical Industry, advocated a pavement made up of a 6-in. concrete base upon which was to be laid 2 in. of a solid binder, covered with a 1½-in. wearing surface, this to take the place of the 1 in. of loose binder and 2 in. of wearing surface now in use. The speaker firmly believes that such a pavement would prove a success on many streets where the traffic now seems to be too heavy for asphalt. A proper selection of the materials for the wearing surface will undoubtedly reduce greatly the excessive slipperiness, although a hard, smooth surface must be slippery to a certain extent unless kept perfectly clean.

The asphalt block pavement is designed for steep grades. The aggregate of which the blocks are formed is coarser than in sheet asphalt, and this, together with the joints formed by the blocks, gives horses a better foothold. Good blocks will make a good pavement, and elaborate experiments are now being made, in order to determine a proper test for, and a proper method of testing, these blocks, so that their value can be determined before they are used.

The bitulithic pavement is expected to be smooth and not slippery. Its inventor started out to improve macadam, but finished by producing a new pavement. It has been used extensively and satisfactorily during the past 5 years, but the speaker's personal

Mr. Tillson. experience with it has been so slight that he will not attempt to discuss it.

Wood pavement has been used in 20-year cycles since the Forties, and has been steadily improved. At first, it consisted of blocks of any convenient wood laid carelessly on a sand base. The pine blocks of the Nicholson patent, laid on planks, followed in the Sixties. The blocks decayed and wore out unequally, and the pavement soon became in disrepute. Cedar and cypress blocks, made of fence posts, were used extensively in the Central West in the Eighties, and, in the present decade, has come the modern treated wooden block. This is a very different proposition from any of the others just described. They all failed from decay. The chemical treatment of the present blocks is expected to prevent this and make durability a question simply of wear. The modern wood pavement, when dry and first laid, is practically ideal. It is smooth, noiseless, and is easily cleaned. It is slippery, however, in moist or frosty weather. That is its greatest fault. If this objection can be overcome, it is bound to have a great future, especially if its preservative treatment is sure. It is expensive, however, and, as all lumber is increasing in value from year to year, it would seem to be difficult to reduce or maintain its cost as at present. This may possibly be done by obtaining different varieties of wood for use. It must be understood, however, that there is no material used in the constructive arts the value of which is so difficult to determine in advance as wood, and great care must be exercised in deciding to use a new variety. The kind which has been generally used is long-leaf, yellow pine, but this, while good, is expensive and is becoming more so from year to year. This wood comes from one section of the country, so that transportation expenses are high. The problem, then, is to discover, if possible, different kinds of wood, in different sections of the country, which can be used to advantage.

In summing up, then, the speaker would say that, in his judgment, the improvements in street pavements in the future are to be brought about by a different use of the materials now in vogue, rather than by the adoption of entirely new materials. That, by studying the needs of the different streets to be paved, by using present materials intelligently, both as to manner and combination, the municipal engineer can bring about results which, if not entirely satisfactory, will be a vast improvement over present practice.

Mr. Haylow. J. H. HAYLOW, ASSOC. M. AM. SOC. C. E. (by letter).—The materials used in the pavements of the future, speaking of a future of from 25 to 50 years, will no doubt be principally the materials of the present. While the pavements of to-day fall far short of perfection, it is due to faulty construction and abuse, rather than to the materials used.

Mr. Haylow.

Of the many thousands of miles of pavements in the United States, only a small percentage has been constructed in a scientific and substantial manner. The construction of a scientific pavement consists, first, in the thorough and effective drainage of the subsoil; and second, in laying a substantial foundation, and unless this is done a full life cannot be obtained from any wearing surface.

The greater part of the mileage of existing pavements is on streets occupied by street-railway tracks, and that portion next to the rails invariably fails first. This is sometimes caused by the faulty construction of the street-railway roadbed, or, by the track not being sufficiently rigid, and sometimes on account of the section of rail used. For instance, a tee-rail should never be used in a street paved with brick, granite block, or asphalt. With a tee-rail, the pavement has no protection whatever from the grind of the wheel flanges and steel tires, the groove in the rail being seldom, if ever, wide enough to be entirely free from the wider flanges and inequalities in the gauge of trucks, and the pavement being subject to the constant wear of steel tires.

Some cities have eliminated the narrow steel tire by ordinance, and, in the writer's opinion, the time is not far distant when all steel tires will become obsolete, their place being taken by rubber or pneumatic tires.

When the steel tire is eliminated, and when city engineers and street-railway officials become convinced that the girder rail—similar to the Trilby type—is the most economical and satisfactory rail for paved streets, and when the portion occupied by tracks is paved with brick, granite block or other material which can be laid on a sand cushion and the joints filled with tar instead of cement grout, then that part adjoining the rail will have the same durability as the remainder of the pavement. Asphalt should never be laid next to the rail.

A first-class street-railway roadbed should possess a certain amount of elasticity, but when the paving joints are filled with cement grout they become ruptured and are no longer impervious to water. The demand at present is not for new, but for a proper, handling of the present, paving materials.

Mr. Richardson.

CLIFFORD RICHARDSON, ASSOC. AM. SOC. C. E. (by letter).—This subject is of very great importance, and Mr. Tillson has brought out some points of great interest, many of which the writer has been insisting upon for years, basing his conclusions on twenty years' experience with various forms of pavements in more than one hundred cities in the United States, in England, and on the Continent of Europe.

There is no question that the failure of most of our pavements is due to lack of foundation as much as to any other defect. This

Mr. Richardson.

is particularly true in the City of New York, where, as far as the writer is aware, a single well-constructed pavement does not exist. In a few, where there is a hydraulic cement foundation, other defects, such as the use of an open binder course in asphalt pavements, result in lack of support to the wearing surface. It is very fortunate that Mr. Tillson, by assuming the office of Chief Engineer of the Bureau of Highways, in the Borough of Manhattan, will be able to inaugurate some much needed changes in the character of the pavements to be laid in the metropolis of the country, and will thus do away with a condition which is a disgrace to such a large city.

The writer does not see that there is any possibility of the immediate introduction of any new form of pavement, but that all improvements must be in the methods used in the construction of those forms now in vogue.

Our granite block pavements do not compare favorably with the best in England and on the Continent of Europe, and we could well imitate the form of construction practiced in the City of Liverpool. As Mr. Tillson says, our blocks, owing to the fact that the surfaces are not well dressed, are made much too large to bed satisfactorily. A granite block, when well dressed, should not be more than 3 in. square. The long blocks now in use make a surface which is far from acceptable.

A large proportion of our brick pavements, even when supported by proper foundations, shows serious defects, owing to the careless way in which the bricks are embedded in the sand or cushion coat between the foundation and the surface. When properly constructed, brick pavements are very suitable for streets of moderate traffic, although they do not possess the smoothness or the freedom from noise of asphalt and wood block.

As Mr. Tillson remarks, we are much in need of some satisfactory method of making accelerated tests, not only of brick, but of wood, asphalt block, and sheet-asphalt surfaces, under conditions approaching in some degree those which exist in actual service.

The writer cannot agree with Mr. Tillson that wood block pavements are to be, to any degree, the pavements of the future, except as luxuries, owing to the scarcity and increasing cost of lumber, the short life of this pavement, and the impossibility of maintaining it in a satisfactory form. It is almost impossible to replace an opening in a wood pavement so that it is not uneven under traffic and plainly visible. London and Paris have had the most extended experience with wood block pavements, and the Municipal Council of Paris is so dissatisfied that it is endeavoring in every way to limit the area paved with wood. In London, streets

which carry heavy travel have to be replaced within at least 7 or 8 years, even where 6-in. blocks are used. Mr. Richardson.

The custom of using large quantities of impregnating material, as practiced in the United States, does not appeal to British and French engineers. The material used for this purpose does not increase the essential resistance of the wood to wear, and it is only necessary to use a sufficient quantity to prevent rotting, at least on streets of heavy traffic.

Blocks having a depth of only 3½ in.—which have been used of late in some of our largest cities—can hardly prove to be satisfactory. After a period of only 3 years, in New York City, they are showing signs of serious deterioration. The experience derived from these pavements will be valuable but expensive.

For many years asphalt blocks have proved extremely satisfactory on residence streets. In Washington, D. C., the writer recently inspected an asphalt block pavement, laid in 1883, which is now in nearly as satisfactory condition as when originally put down; but attempts to use this form of pavement on streets carrying moderately heavy traffic, as in New York City, have resulted disastrously. A good example of this can be seen on Fourth Avenue, between Thirty-second and Thirty-fourth Streets, in New York, where the blocks began to go to pieces within 18 months, and have been largely replaced within 2 years.

There is, no doubt, opportunity for improvement in the character of the blocks by using a cementing material less susceptible to temperature changes than that which has been used. In order to make it possible to store the blocks at the plant, and to transport them to the street without losing their shape, it has been necessary to use a much harder cement than was satisfactory under traffic. Some of the native bitumens and fluxes now available have made it possible to prepare a cement which is sufficiently soft at winter temperatures to make a block which will not disintegrate under traffic at that season, and at the same time be hard enough to permit of handling and storing in our hottest summer temperatures in the sun.

Within the last few years very decided improvements have been made in the form of construction of sheet-asphalt pavements, although these improvements, owing to the inertia of municipal authorities, have not been generally adopted. The best form of construction for a sheet-asphalt surface has recently been described by the writer, in a paper read before the New York Section of the Society of Chemical Industry, and details in regard to this need not be gone into here.

Bituminous concrete pavement is one of the forms recently developed to a considerable extent. When the cementing material is

Mr. Richardson.

a bitumen of suitable character, and not coal-tar, such pavements serve extremely well on streets of light traffic. One constructed by the writer in Muskegon, Mich., in 1902, has been entirely successful after 5 years of constant use. Pavements of this description will, no doubt, be used to a considerable extent in the future, but they must be constructed on practical and not on theoretical lines. Already the large stone used in the original pavements of this type has been abandoned for smaller sizes, not exceeding 1 in. in diameter; and the quantity of fine material has been increased to a marked degree.

This form of pavement is not satisfactory on streets of heavy traffic, owing to the fact that the coarse stone is torn out very readily by the impact of horses' shoes, with resulting disintegration of the surface.

It seems to the writer that Mr. Tillson has not paid sufficient attention to the fact that that form of pavement is most desirable, especially in American cities where so many openings are made in the streets, which, while desirable in other respects, can be maintained most perfectly and most economically. It is certainly most unfortunate that our municipal engineers have done nothing toward determining the lasting properties of the various forms of pavements, under traffic of various concentration, and also the cost of maintenance of each type. For this purpose, very complete counts of the traffic should be kept in every city, in order to determine the cost of various pavements annually per ton of material hauled over them.

The writer is convinced that much better pavements could be laid by contractors if municipalities were prepared to pay a somewhat increased price. There is no economy in laying a pavement because it is cheap, if a stronger form of construction at a higher price would eventually result in a smaller annual cost.

Another unfortunate state of affairs in American cities is that the average citizen believes that when a street is once paved it is finished for a generation, or for all time, and little or no attention is given to its maintenance. In one city which the writer has in mind, at a meeting of the Board of Public Works, it was stated by a city official, that an asphalt pavement was of no value, and that no more pavements of this kind were desired in that city because, after the expiration of a 10-year guaranty, nothing having been expended on maintenance for 5 years, the pavement went to pieces.

Finally, it may be remarked, what is needed in the United States is not new material for the construction of street surfaces, but a proper and improved form of construction of those which have been in use for the last 20 years, together with a study of

the actual cost per annum per ton of traffic carried per linear foot of street. Unfortunately, data of this description are almost entirely wanting at present. Mr. Richardson.

That there is a large field for improvement in the character of pavements is quite evident, and this improvement must lie with the municipal engineer, who will probably not make the desired move until the citizens demand that he shall do so. The best contractors are always in favor of doing the best work compatible with the price they receive for it.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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ELECTRIC RAILWAYS.

An Informal Discussion at the Annual Convention, July 10th, 1907.*

SUBJECT FOR DISCUSSION:

"(*a*) What are the factors which determine the maximum economical grade for electric railways?

"(*b*) In establishing direct lines with heavy grades, under what conditions will it be found practicable to use electric locomotives and gas-engine generating stations, rather than traction by steam locomotives?"

BY GEORGE GIBBS, M. AM. SOC. C. E.

Mr. Gibbs.

GEORGE GIBBS, M. AM. SOC. C. E.—It is difficult to furnish material for discussion of a question having such scope as the first part of this topic, except in the shape of generalities, which are either obvious or of little use in the special case which the engineer may have in mind. The length of line, the character and density of traffic, the location and length of grades, all have important bearings upon the economies, constructing and operating, in any railway proposition. It is probable, therefore, that the proposer of the question had in mind a discussion of the factors peculiar to the method of traction, rather than those affecting the location of railway lines in general. These factors result from the method of application of the power to the trains, and from the interconnected character of the apparatus which makes up the motive-power system.

* Further discussion, had at the Convention, will be published subsequently, and additional written discussions are invited.

Mr. Gibbs.

On a steam railway the power plants are the locomotives; an electric road has its power system jointly in the locomotives (or the motor cars), in the continuous power conductor along the line, and in the central power-house. In the steam railway, therefore, the first cost of power equipment is fixed by the number of locomotives, independently of the location, or the length of line, or other outside considerations; with the electric proposition, the first cost of the power system is affected, not only by the number of locomotives or motor cars, but also by the magnitude of the other items of power equipment, and these items depend largely upon the grades, their length, and possibly their position. For instance, we can readily imagine a line with grades located in such a way that, with a given train interval, all trains may be ascending simultaneously; in such a case, the line equipment and power-houses must be designed to supply all trains taking power simultaneously, even if this maximum power is only needed for a small percentage of the total time. A location with the grades differently selected, even if the maximum gradient is not altered, might readily result in a much lower maximum demand at the power-house, and a consequent reduction in cost of the power system. Length and position, as well as rate of grades, therefore, are of much importance in an electric railway proposition.

The quantitative importance of these factors, of course, depends upon the character of the business; thus, where the traffic is very dense, requiring the operation of trains at short intervals, the relative location of grades is not as important as with infrequent train units, because, as the number of trains is increased, those ascending and descending the grades at any one time tend to balance, resulting in a relatively steady load on the power-house. The length of grade in an electric proposition has a peculiar importance because of the fact that electric motors have a rating in which the time limit comes in. Thus, for short maximum grades, the limit of motor capacity is in the commutation of the current; with long grades, the limit is in the heating of the motors, due to the cumulative effect of passing current through the motors, the resulting heat being not entirely dissipated by radiation.

As to maximum practicable gradients; this factor is generally a less limiting one in electric traction than in steam. For trains composed in whole or in part of motor cars, the question of adhesion may generally be dismissed, because the limiting grade, from the standpoint of safety, is generally less than that dictated by the adhesive limit. Even with locomotive trains, the problem is less serious in electric than in steam traction, because of the large proportion of the electric locomotive weight available for adhesion, and because of the facility with which trains may be double-headed

Mr. Gibbs. with electric locomotives; this arises from the fact that by multiple control two or more locomotives become in effect a single unit, and are not open to the objections of dual control, as in operating two or more steam locomotives on one train.

From the two factors, namely, the higher adhesion ratio and the selection of grade locations, it may result that, with an electric railway line, the economic grade may be greater than that possible with steam traction. For certain kinds of electric railways in a flat country, for instance the interurban trolley road, this facility for surmounting short but very heavy grades without reaching the adhesive limit is of great importance in separating steam and electric grades at crossings, without excessive cost, either for grading or for power plant.

The effect of gradient upon operating cost cannot well be discussed for the general case; in some cases the grades may have little or no effect, if they are short and the traffic is heavy; in other cases their length and location may have an important effect upon the quantity of fuel required and the economy of power-house operation. Of course, the cheaper the fuel, the less the importance of this factor in determining the line location.

Summing up, therefore, some important points to be considered in laying out an electric traction proposition are:

1.—The effect of density of traffic in averaging the load requirements at the power-house;

2.—The effect of location of grades, especially in infrequent service, in averaging load requirements at the power-house;

3.—The wider latitude in fixing the maximum grades because of the greater adhesion ratio;

4.—Limiting commutating effects on short grades;

5.—The motor heating effects on long grades;

6.—The less effect of grades on speeds because of the greater accelerating rate possible.

In order to use gas-engine stations successfully, for any electric traction project, it is necessary, of course, first, that gas engines and generators be obtainable of the proper characteristics for such work, and, second, that they will prove advantageous and economical. The form of the question appears to limit the subject to gas-engine prime movers for electric lines, rather than consideration of electric traction *versus* steam traction. In laying out the project in question, however, it is presumed that it would first be essential to determine whether electric traction of any kind would be advantageous, and then whether gas-engine would be better than steam or water-power prime movers.

A general discussion of electric *versus* steam traction, of course, opens up a vast subject, and to indicate even the treatment would

Mr. Gibbs.

be beyond the limits of a brief opening discussion. Generally stated, for heavy grade work it may often be advantageous to adopt electric traction, not only because of economy of operation, but because of an increase in the capacity of the line consequent upon the use of exceptionally powerful electric locomotives which will enable the ruling loads to be taken over the grade without doubling; also because of the convenient application and control of electric locomotives, and because of the factors mentioned in connection with the discussion of the previous question.

Having determined that it will be economical or advantageous to use electric traction, it does not necessarily follow that gas engines would be the best means for producing power. Where water-power is available, and may be developed at moderate cost, on the line or within reasonable transmission distance of it, it will be found that such power will be more economical than either gas or steam. Where water-power is ruled out, and where the railroad is located within a short distance of coal mines, it may be that a steam-generating station would be more economical than a gas-engine station because of the lower first cost of the steam-generating plant.

In order that the gas-engine plant may be used economically, it is necessary that, as before stated, the machinery be available in units of proper size, that the details be worked out practically, and that they compare favorably with steam or water in first and operating costs. Doubtless these questions will be discussed in connection with the subject of gas engines, and, therefore, it may be stated here, that, from the point of view of economy of power, the gas-engine plant promises well, but from the view of availability, there appear to be at the present time two important limitations: the first is in the small over-load capacity of the gas engine, which is disadvantageous for fluctuating railroad loads, and the second is in the fact that gas engines and producer plants, up to this time, have been developed in relatively small units. Of course, it is true that some large gas engines have been built, but they can hardly be called a commercial article yet for general application to railway purposes.

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GAS ENGINES.

An Informal Discussion at the Annual Convention, July 10th, 1907.*

SUBJECT FOR DISCUSSION:

"(*a*) What is the best apparatus and most economical system for cleaning producer or furnace gas, to be used in gas engines?

"(*b*) To what extent is ordinary producer gas, made from bituminous coal, used in gas engines, and what practical results have been obtained by any methods for removing tar or soot?"

BY MESSRS. JAMES CHRISTIE AND ROBERT HEYWOOD FERNALD.

Mr. Christie.

JAMES CHRISTIE, M. AM. SOC. C. E.—When furnace or producer gases are to be used in engines, it is necessary that the dust, or tarry matter, in the gas be removed entirely or nearly so. It is also necessary that sulphurous gas, if present to an objectionable excess, be reduced, or that the engine and its accessories be designed and constructed so that corrosion or electrolytic action will not ensue.

The necessity of clean gas in the engine is so important that scrubbers or washers, of the form and type heretofore used in connection with regenerators, etc., have not proved generally satisfactory, and, as a consequence, some trouble has developed in engines using gas insufficiently cleaned.

The gas must also be sufficiently cooled, and it is desirable that it should contain as little moisture as possible, as water vapor reduces its efficiency; and, as the various forms of washing apparatus

*Further discussion, had at the Convention, will be published subsequently, and additional written discussions are invited.

use a spray of water to remove the dust, the gas at the engine will be saturated, to a greater or less extent, depending on its temperature, unless special filters or vapor-absorbing devices are used. Mr. Christie.

Washing apparatus can be divided into four general types as follows: The baffle system; the coke scrubber; and two mechanical methods, one in which slowly revolving wetted surfaces are presented to the flowing volume of gas; the other a high-speed machine depending on centrifugal action. In blast-furnace practice, the usual dust catchers remain, as a preliminary, to reduce the work of the washer.

The first named types are so well known (or descriptions thereof are so readily accessible) that it is unnecessary to give their details here. The several mechanical washers are controlled by patent rights, therefore reference for description should be made to the manufacturers. It appears, however, that apparatus of the centrifugal type, especially when required to be of large capacity, as in blast-furnace practice, have proved highly efficient, and economical in space occupied and in water used. In recent American practice a removal of 97% of the solid impurities is reported.

The size and cost of the various apparatus depend on the amount of solids to be removed from the gas, and on the degree of purity required. Some manufacturers claim to remove the dust, so that not more than 0.01 gr. per cu. ft. of gas will remain. In a general sense, and for washers of considerable capacity, it may be assumed that the water consumption will vary from 10 to 25 gal. per 1 000 cu. ft. of gas washed; and the power required for mechanical treatment, from 0.10 to 0.20 h. p. per 1 000 cu. ft. of gas per hour, according to the amount of impurity present.

In producer practice, for power purposes, the fuel used has heretofore been confined to anthracite or other non-coking coal, and the coke scrubber is generally used for gas cleaning with the water spray for washing, and a supplementary coke chamber without water for drying the gas.

The abundance and cheapness of natural gas, throughout such a large area of the Middle States, has hitherto prevented any development of bituminous coal producers for power gas. The constant poking required to break up the coke, and the presence of either tar or soot or both, renders the production of gas with bituminous coking coal a more difficult problem than when non-coking fuel is used.

Recently, however, some promising work has been done with coking coal, and the experiments made at St. Louis under the direction of the United States Government have been instructive.

When bituminous coal is gasified in the producer under low pressure and slow combustion, say with a coal consumption of less

Mr. Christie. than 10 lb. per sq. ft. of fire bed, the quantity of tar suspended in the gas is comparatively large, the quantity of soot is small, and the temperature of the issuing gas is low. On the contrary, with more active combustion, when the consumption of coal is from 20 to 30 lb. per sq. ft. of fire bed, as in some mechanically-operated producers, the quantity of tar is small, or entirely disappears, the discharge of soot or lampblack is greater, and the temperature of the gas is much higher.

The quality of the gas appears to be about the same in each case. In addition to the soot carried over in the latter case, a considerable quantity of coke dust frequently appears; this comes from the fine particles of coal which fall through the atmosphere of high-temperature gas and are light enough to be wafted forward in the issuing stream of gas.

In modern producer practice, considerable quantities of steam are used advantageously—more than 1 lb. per lb. of coal consumed is common practice—with a result that the gas contains from 25 to 30% of its total volume of CO, or 10 to 15% of hydrogen. The steam also prevents the formation of hard clinker, and facilitates the discharge of the ash, the limit in its application being the amount that can be used without dampening combustion, or that can be decomposed in its passage through the incandescent fuel.

For the economical use of this gas in engines, it becomes necessary to provide apparatus which will cool the gas, utilize the extracted heat, remove or otherwise utilize the tar, remove and utilize the soot, and dry the gas after it has passed through a treatment with water.

For the economical use of this gas in engines, it becomes necesplished successfully by applying the heat to generate steam for the producer, or for preheating the air supply, or for both. Various methods of cleaning are proposed, but are still in the experimental stage. The tar problem has been handled in two ways: Separation by centrifugal action, as accomplished in the Government experimental plant at St. Louis;* and by the decomposition of the tar by passing the gas through a supplementary bed of incandescent anthracite or coke. The latter method is reported as being applied successfully in Germany to fuels of the lignite class, and has been applied to a limited extent in the United States, especially in the production of composite gas, which forms a specialty with manufacturers of power-gas apparatus.

This latter method of utilizing the tar has been accomplished by various methods, which differ in the details of application, and are claimed to be covered by patents. It appears, however, to be the most successful system for the complete disposal of tar, except

* Bulletins 48 and 261, U. S. Geological Survey.

by the use of auxiliary attachments to the mechanical cleaner, which require attention and renewal. Mr. Christie.

Obviously, the respective economies of the two methods depend somewhat on the demand for and value of tar in the vicinity. As the weight of the tar will be from 5 to 10% of the coal consumed, and sometimes much more when lignite is used in the producer, its salable value is an important factor in the problem.

When a large quantity of soot is formed, its removal has always been difficult, as it mixes with water very reluctantly in the scrubber, and is apt to create a nuisance, by the trouble involved in handling it, or by its obstruction of the gas passages. Sulphurous constituents in the gas have been dealt with by passing the gas through a mass of oxidized iron cuttings, a process which involves frequent renewal of the iron, if the content of sulphur is high. It is believed, however, that trouble from this source is not serious, if proper precautions are observed in the engine to avoid contact between materials which may promote corrosion or electrolytic action.

Altogether, it cannot be asserted that the generation of producer gas for power purposes, from bituminous coal, is yet in a satisfactory state of development. It will be understood that no reference is made here to the by-product recovery system, which is a distinct feature of producer practice.

ROBERT HEYWOOD FERNALD,* ESQ. (by letter).—In presenting the following discussion, the writer's remarks are confined to the utilization of producer gas for power purposes in the United States. Mr. Fernald.

Rapid Development of the Gas Engine.—It was during the latter part of the nineteenth century that the gas engine found its way to the market, and, although many types have been produced in the past 20 or 30 years, it is only within the past 5 or 6 years that the development of large engines has been noted. This development started in Germany, Belgium, and England some 8 or 10 years ago, but marked progress has been limited to the past 6 years.

For many years the natural fuel of these internal combustion engines was city gas, but even this was too expensive except for engines of small capacity, and it was seldom found feasible to operate engines of more than 75 h. p. on this fuel. Cheap gas was essential for the development of the gas engine, but the early attempts in this direction were somewhat discouraging, and, for a time, the probability of encroaching to any extent upon the field occupied by the steam engine was very remote.

The theoretical possibilities of the internal combustion engine

* Professor of Mechanical Engineering, Washington University, St. Louis, Mo., and Engineer in Charge of Gas Producer Division of the Technologic Branch, United States Geological Survey.

Mr. Fernald. operated upon cheap fuel promised so much that the practical difficulties were rapidly overcome, with the result that steam boilers and engines in many plants were replaced by gas engines, and, at the present time, the internal combustion engine is rapidly becoming a serious rival of the steam engine in many of its applications.

The development of the gas engine in point of size has been exceedingly rapid. It was only 7 years ago that a 600-h. p. engine, exhibited at the Paris Exposition, was regarded as a wonder, but, four-cycle, twin-tandem, double-acting engines to-day run as high as 6 000 h. p.

Development of the Gas Producer.—This rapid advance of the large gas engine has been made possible by the great strides which have been made in the production of cheap gas directly from fuel through the aid of the gas producer. An early form of producer introduced in Europe, and one that is in very general use to-day, both abroad and in the United States, is known as the suction producer, named from the fact that the engine develops its charge of gas in the producer by its own suction stroke. Although this type of producer is used very extensively, its use is confined to small installations, usually not exceeding 150 h. p. As far as known, the first suction producer operated in the United States was installed in 1903, although other types of producers were tried in this country a few years earlier. A serious limitation to producers of this type has been the fact that, owing to the manner of generating the gas, no tarry fuels could be used, thus barring bituminous coals, lignites, peats, etc. The fuels in most common use for suction producers are charcoal, coke, and anthracite coal, although attempts are being made to construct suction plants so that they can be operated on the bituminous, or tarry, coals.

In order to meet the demand for the concentration of power in large units, instead of operating a large number of engines of small power capacity, the pressure producer came into existence. This producer develops its gas under a slight pressure, due to the introduction of an air and steam blast, and the gas is stored in a holder until such time as demanded by the engine. Owing to the fact that the gas may be stored in a tank before passing to the engine, and also because the gas is produced under pressure and does not depend on the suction of the engine for its generation, it is possible to introduce the necessary machinery for the removal of tar and other impurities from the gas, thus opening the way to the use of bituminous coals and lignites. Following closely upon the pressure plants came the down-draft producers, which fix the tar as a permanent gas and, therefore, can use the bituminous coals and lignites.

These pressure and down-draft plants have been in operation for

Mr. Fernald.

the past few years, but, in most cases, until very recently, the fuel has been anthracite coal, although occasionally plants ventured on the use of a few well-tried bituminous coals, known to be especially free from sulphur, and low in ash and in tar production. It remained for the United States Geological Survey, in its testing plant at St. Louis, to attempt the use of any and all bituminous coals, lignites, and peats, without reference to the amount of sulphur or tarry matter found in the fuel. It is gratifying to note that every coal received has been run through the producer, and that the results have been more than satisfactory.

Number of Installations in the United States.—Within the past 2 or 3 years, the development in the gas-producer industry has been very rapid. At the present time there are probably twenty companies in the United States manufacturing gas producers for power purposes. At least twelve of these are fully established on a commercial basis and are in position to give proper guaranties when installing plants.

About one hundred and fifty gas-producer power plants, ranging in size from 20 to 6 000 h. p., are now in operation in the United States. One company alone reports twenty odd installations, averaging more than 2 000 h. p. each, and nearly as many more, averaging about the same size, contracted for or now being erected. The horse-power represented by these one hundred and fifty installations amounts to about 70 000.

The number of installations and the persistent development have already led the National Board of Fire Underwriters to issue special rules and requirements for the "Construction, Installation and Use of Coal Gas Producers (Pressure and Suction Systems)."

Of the total number of installations in the United States, it is interesting to note that about two-thirds are suction plants which operate on anthracite coal, charcoal being used in a few cases. Bituminous coal is used in approximately one-third of the installations, but this one-third of the number of plants probably covers in the neighborhood of from 65 to 75% of the aggregate horse-power rating, or in the neighborhood of 50 000 h. p.

Tests of the United States Geological Survey.—This gas-engine, gas-producer problem, with its possibility of driving out the steam engine in many large installations, has become so extremely important that the United States Government has made special provision for producer-gas tests at its coal-testing plant originally installed in connection with the Exposition at St. Louis. These tests have resulted in furnishing very valuable data on the relative consumption of coal per horse-power per hour when used by the steam plant and by the gas plant.

The steam plant upon which the tests were made consists of two

Mr. Fernald.

210-h.p. Heine boilers which furnished steam for a 250-h.p., simple, non-condensing Corliss engine. This engine was belted to a Bullock electric generator.

The producer-gas plant is a Taylor pressure-gas producer furnished by R. D. Wood and Company, of Philadelphia. This producer, designated as No. 7, is of 250 h. p. capacity. Together with the producer, are the usual economizer, scrubber, tar extractor, purifier, and holder.

The gas engine installed is a three-cylinder, vertical, Westinghouse gas engine, with cylinders 19 in. in diameter and having a 22-in. stroke, rated at 235 b. h. p. on producer gas.

The engine was belted to a 6-pole 175-kw. Westinghouse direct-current generator. The load on the generator was controlled by, and the energy developed was dissipated through, a water rheostat especially constructed for the purpose.

After installing this plant in 1904, one hundred and sixty-two producer-gas tests were made, prior to moving the plant to the Jamestown Exposition grounds, in March, 1907. The fuels used have been bituminous coals, lignites, and peats, from twenty-six different States, as indicated in Table 1.

TABLE 1.—COALS, LIGNITES, AND PEATS TESTED BY THE UNITED STATES GEOLOGICAL SURVEY AT ITS ST. LOUIS PLANT.

	Number from each State.	
BITUMINOUS COALS TESTED:		
Alabama	3	
Arkansas	2	
Illinois	29	
Indiana	15	
Indian Territory	2	
Iowa	1	
Kansas	2	
Kentucky	5	
Missouri	1	
New Mexico	3	
Ohio	10	
Pennsylvania	13	
Tennessee	8	
Utah	1	
Virginia	5	
Washington	1	
West Virginia	14	
Wyoming	5	120
LIGNITES TESTED:		
Arkansas	1	
California	1	
Colorado	1	
Montana	3	
North Dakota	4	
Texas	4	
Washington	3	
Wyoming	1	18
Carried forward		138

	Number from each State.	
MISCELLANEOUS FUELS TESTED:		
Brought forward		138
Argentine	1	
Brazil	1	
California and Cinders	2	
Florida Peat	1	
Massachusetts Peat	1	
Rhode Island Anthracite	1	
Virginia Pea Anthracite	1	
Coke Breeze	1	
Miscellaneous Refuse	1	
Coke	1	11
DUPLICATE TESTS OF COALS:		
Illinois	2	
Indiana	4	
Kansas	1	
Ohio	1	
Pennsylvania	2	
Tennessee	1	
West Virginia	1	12
DUPLICATE TESTS OF LIGNITES:		
North Dakota	1	1
Total tests made		162

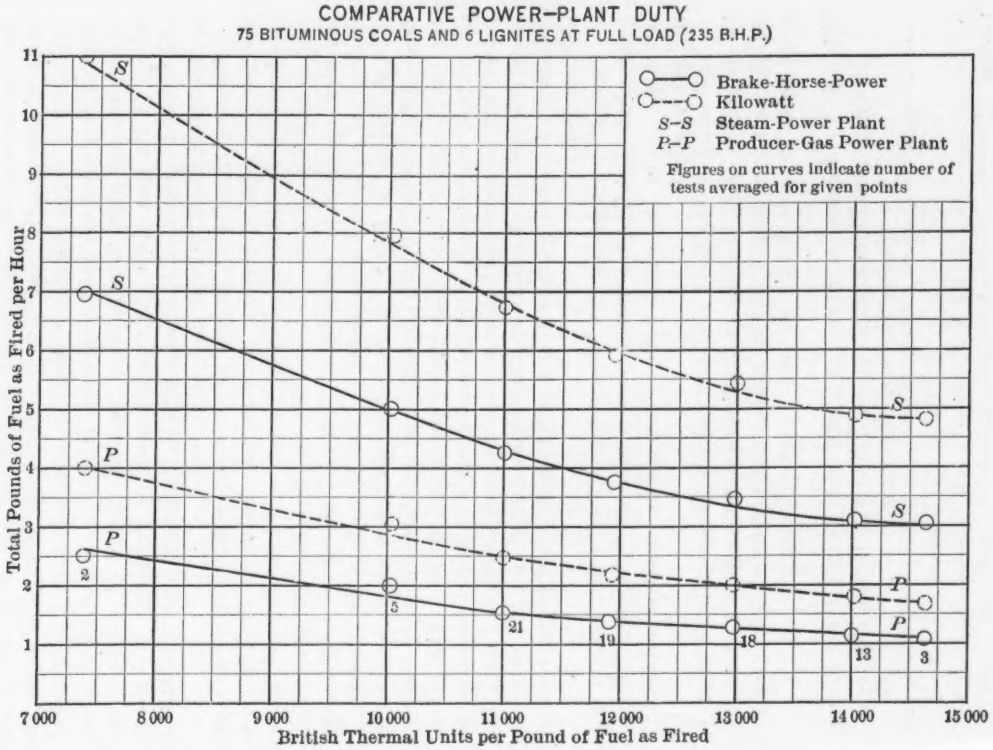

COMPARATIVE POWER-PLANT DUTY
75 BITUMINOUS COALS AND 6 LIGNITES AT FULL LOAD (235 B.H.P.)
Brake-Horse-Power
Kilowatt
S–S Steam-Power Plant
P–P Producer-Gas Power Plant
Figures on curves indicate number of tests averaged for given points
Total Pounds of Fuel as Fired per Hour
British Thermal Units per Pound of Fuel as Fired
7 000
8 000
9 000
10 000
11 000
12 000
13 000
14 000
15 000
1
2
3
4
5
6
7
8
9
10
11
S
P
2
5
21
19
18
13
3

FIG. 1.

Mr. Fernald.

No Injurious Effects from Sulphur.—Especial attention is called to the fact that, during all tests conducted at this plant, no attempt was made to remove the sulphur from the gas before it entered the engine. Considerable controversy has arisen in various parts of the country regarding the influence of sulphur upon the cylinders of a gas engine, leading, in some cases, to the introduction of this question into important lawsuits. The engine in use at the testing plant has received the full charge of sulphur contained in the gas, since the establishment of the plant, and shows absolutely no signs of injurious effects, although coals containing as much as 8.1% of sulphur have been used.

Relative Results of Steam and Producer-Gas Tests.—In considering the relation between the economic results of the two types of plants under discussion, namely, steam and producer gas, attention is called to the fact that, to-day, in the ordinary manufacturing plant operated by steam power, less than 5% of the total energy in the fuel consumed is available for useful work at the machine.

The curves in Figs. 1 and 2 show the great economy secured from seventy-five bituminous coals and six lignites when used in the gas producer instead of under the steam boiler. The results of the tests are officially reported on the basis of switch-board horse-power, but, in order that they may be of more practical value, they are given here on the basis of brake-horse-power and kilowatt—the efficiency of electric generator and belt in each plant being assumed as 85 per cent.

Especial attention should be called to the fact that several low-grade coals and lignites, which have proved of little value or even worthless under the steam boiler, have given excellent returns in the gas producer.

The ratios of the total fuel per brake-horse-power-hour required by the steam plant and the producer-gas plant under full-load conditions, not counting stand-by losses, are presented below as derived from 75 coals, 6 lignites, and 1 peat (Florida).

TABLE 2.—Ratios of Fuels as Fired per Brake-Horse-Power-Hour under Boiler to Fuel as Fired per Brake-Horse-Power-Hour in Producer.

	Coals.	Lignites.	Peat.
Average	2.7	2.7	2.3
Maximum	3.7	2.9	....
Minimum	1.8	2.2	....

In the case of the results for the producer-gas tests, the figures include not only the coal consumed in the gas generator, but also

British Thermal Units per Pound of Dry Fuel

Fig. 2.

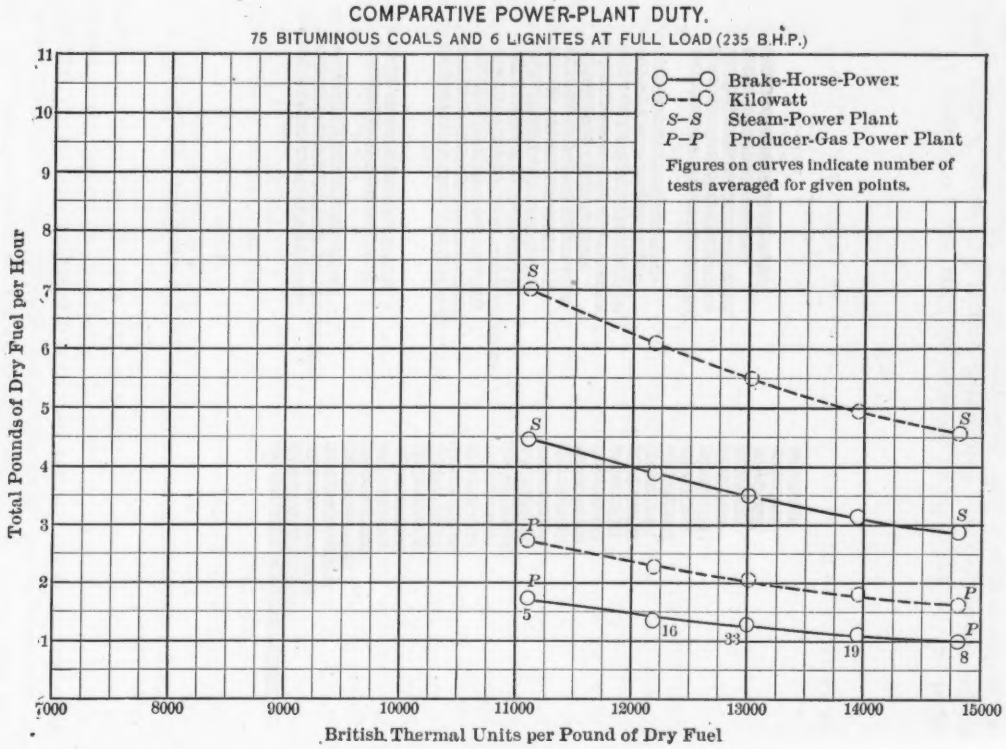

COMPARATIVE POWER-PLANT DUTY.
75 BITUMINOUS COALS AND 6 LIGNITES AT FULL LOAD (235 B.H.P.)
Brake-Horse-Power
Kilowatt
S–S Steam-Power Plant
P–P Producer-Gas Power Plant
Figures on curves indicate number of tests averaged for given points.
Total Pounds of Dry Fuel per Hour
British Thermal Units per Pound of Dry Fuel
7000
8000
9000
10000
11000
12000
13000
14000
15000
1
2
3
4
5
6
7
8
9
10
11
S
P
5
16
33
19
8

FIG. 2.

Mr. Fernald. the coal used in the auxiliary boiler for generating the steam necessary for the pressure blast, that is, the figures given include the total coal required by the gas-producer plant.

The relation between the coal required by the steam and producer-gas plant may be seen more clearly by an examination of Fig. 3, which presents graphically the results from thirty Illinois bituminous coals.

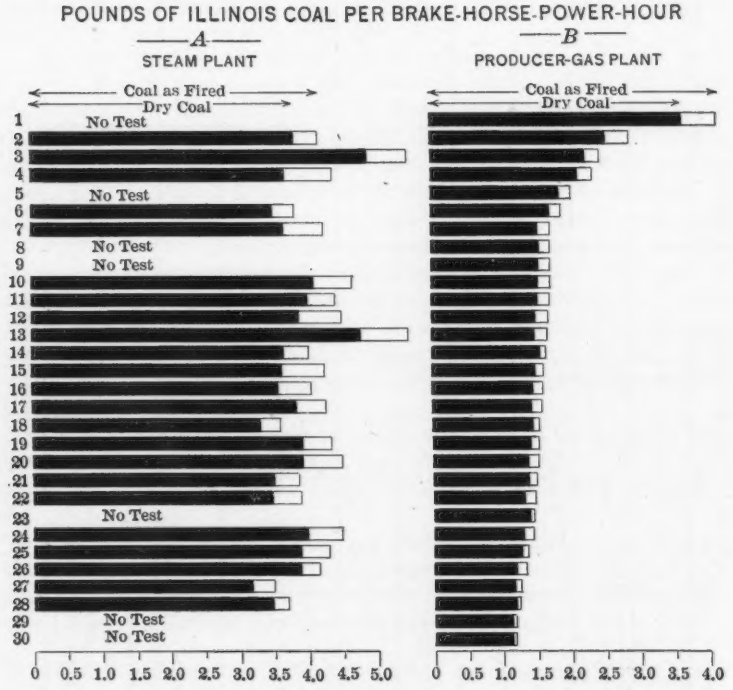


FIG. 3.

In considering the possible increase in efficiency of the boiler tests with a compound engine substituted for the simple engine used, the fact should not be overlooked that a corresponding increase in the efficiency of the producer-gas tests may be brought about under corresponding favorable conditions.

Too much emphasis cannot be given to the fact that all the tests upon bituminous coals, lignites, and peats were made in a

producer designed primarily for anthracite coal. It is, in fact, marvelous that any single plant can handle such a range of fuels. Not only is the producer passing through a transitional period, but the gas engine must still be regarded in the same light. In the larger sizes, the vertical, single-acting engine is being replaced by the horizontal double-acting type. Other changes and improvements are constantly being made which tend to do for the efficiency of the gas engine what compounding and tripling the expansions have already done for the steam engine. Mr. Fernald.

The engine used in the tests reported is, as already stated, of a type that is rapidly becoming obsolete for this size, namely, vertical, three-cylinder, single-acting.

A brief consideration of these points will lead at once to the conclusion that the producer-gas plant and steam plant used in these tests compare very favorably, and that any increase in efficiency in the boiler tests which might result from using a compound engine can be offset by the introduction of the more modern type of gas engine and a producer plant designed to handle the types of fuel used.

It should again be noted that many fuels are not fit to use under boilers. Many of these poor fuels have been used with the greatest ease in the gas producer, thus opening the way for the utilization of many fuels which have heretofore been regarded as practically of no value. Several of the poorest grades of bituminous coals have shown remarkable efficiency, and the lignites and peats have also responded with great readiness to the demands of the gas producer, thus opening the way to the introduction of cheap power into large districts which, thus far, have been commercially unimportant owing to the lack of industrial opportunities.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

JOHN EUGENE CHENEY, M. Am. Soc. C. E.*

DIED SEPTEMBER 25TH, 1906.

John Eugene Cheney was born in Lowell, Massachusetts, on February 12th, 1847. His parents were John S. Cheney and Cynthia Cram. His father was a direct descendant of Hannah Dustan. His parents lived originally in Ware, New Hampshire, from which town they moved to Lowell. In that city his father was Superintendent of the Merrimack Mills for many years, and afterward was engaged in manufacturing spools, bobbins, and shuttles.

In 1865 Mr. Cheney was graduated from the Lowell High School, and at once entered the Lawrence Scientific School of Harvard University. He was obliged to leave, however, after completing one year of the two-year course, but, in 1900, in recognition of the valuable professional work which he had done, the University conferred upon him the degree of S. B. as of the Class of 1867. This degree was prized more highly by Mr. Cheney than if it had been obtained in the usual way.

Mr. Cheney's first work, after leaving the Lawrence Scientific School, was at the Charlestown Navy Yard. He was also for a time with E. D. Leavitt, Jr., M. Am. Soc. C. E. He entered the employ of the Louisville Bridge and Iron Works, Louisville, Ky., in 1870, and remained there four years, obtaining valuable experience which served as the foundation of his future eminence as a structural engineer. He became an Assistant Engineer in the service of the City of Boston in 1874, and was appointed Assistant City Engineer in 1885. This position he held until his death, having acted frequently as City Engineer in the absence of the latter. During this period he had charge of the city bridges, and his work was of great value to the city, as he proved himself to be a very conscientious, capable and thorough structural engineer.

In Mr. Cheney's thirty-two years of service nearly all the city bridges were built or renewed under his supervision. The bridges which he built were of good design, substantial, and appropriate to their surroundings, and were constructed economically. There are in Boston many examples of the retractile drawn-bridge, a peculiar type of movable bridge having certain advantages for low-grade crossings. This type was developed by Mr. Cheney from a crude and

*Memoir prepared by the Secretary from information contained in an obituary notice for the Boston Society of Civil Engineers, by a committee composed of George F. Swain, E. D. Leavitt and Frederic H. Fay, Members, Am. Soc. C. E.

unscientific structure to one scientifically and economically designed, and remains as a distinctive feature of his work. He also perfected the wooden-leaf bascule bridge, and was among the first to build these bridges of iron. In connection with machinery for draw-bridges and various mechanical plants his work gained for him a deserved reputation as a mechanical engineer. He had an extensive experience with tide-water foundations built under the peculiar conditions found about Boston, and was recognized as an authority in such matters.

He designed and superintended the erection of a great many bridges, among them being the Charlestown Bridge, constructed under the direction of the Transit Commission, and containing the widest draw-span in existence. The new Cambridge Bridge, between Boston and Cambridge, its graceful arches making it the most beautiful bridge of its kind in America, was probably his greatest work.

In addition to his work for the City of Boston, Mr. Cheney's abilities as a structural engineer brought him many commissions from outside parties. For a number of years he was Consulting Bridge Engineer for the Concord Railroad, the Boston, Concord and Montreal Railroad, and their successor, the Concord and Montreal Railroad, and designed most of the metal bridges on that system, and also the train-shed at Concord, New Hampshire. He was also Consulting Engineer for the Connecticut River Railroad and the Massachusetts Central Railroad. He was consulted by many counties, cities, and towns throughout New England in regard to highway bridges. His advice was also sought by many architects in reference to foundations and steel-frame buildings. Among such structures in Boston may be mentioned the Exchange Building, the Exchange Club, the Tremont Building, the Tremont Temple, the New England Conservatory of Music, and the Central Building. The silverware factory at Concord, New Hampshire, built by the William B. Durgin Company, is a meritorious example of mill construction designed by him.

Mr. Cheney always studied his problems with great care, but was never afraid to adopt a novel or untried form of construction or a new idea after he had convinced himself that it was right. His designs were all ingenious, economical, well thought out, and well adapted to the conditions of each case. He was soon recognized as an able engineer, and as taking rank with the best structural engineers in America.

In 1875 he was married to Ellen M. Neal, daughter of the Hon. Peter M. Neal, of Lynn. After returning to Massachusetts, he lived in Lynn for ten years; he then moved to Boston, and at the time of his death and for some time previous, had been living in the suburb of Brighton. He died suddenly, of heart trouble, on September 25th,

1906. Mrs. Cheney, a son, and a granddaughter survive him. His son, Herbert Neal Cheney, also a graduate of the Lawrence Scientific School, is following his father's profession, being at present with the Boston Consolidated Gas Company.

Mr. Cheney was a member of the Massachusetts Society and Boston Chapter of the Sons of the American Revolution, and of the Society of Colonial Wars in Massachusetts. He was also a prominent member of the Boston Society of Civil Engineers. He was elected a Member of the American Society of Civil Engineers on May 7th, 1884.

While of a very modest and retiring disposition, Mr. Cheney was, nevertheless, a man of great force and determination. All who knew him loved and respected him, on account of his high professional acquirements and his lovable nature and sturdy integrity. He was always thoughtful of the rights of others, and was a man who would never do a mean thing. His brother members in the Boston Society of Civil Engineers have written of him:

"His memory will long be kept green in the hearts of those who knew him, and his death leaves a vacancy in his professional as well as his personal circle which will not soon be filled. Men like him, so strong, so modest, so capable, so thoughtful, so kind, so helpful, are rare indeed."

JOSEPHUS CONN GUILD, M. Am. Soc. C. E.*

DIED FEBRUARY 25TH, 1907.

Josephus Conn Guild was born in Nashville, Tennessee, on January 4th, 1862. His father was Major George B. Guild.

His primary education was received from the Mims School, at Nashville, from which he entered Vanderbilt University, receiving from that institution M. A. certificates in the Scientific Schools in the summer of 1883. Immediately thereafter he was appointed Assistant State Geologist. Resigning from this office a year later, Mr. Guild accepted an engagement as Superintendent and Engineer of the Refugio Gold and Silver Mining Company, Durango, Mexico.

After nearly a year spent in the tropics, to which he always had an aversion, he returned to the States, securing a re-appointment as Assistant State Geologist.

From 1885 to 1887 he held the position of Inspector of Mines, State of Tennessee, forming, at the same period, the partnership of Dickerson and Guild, Civil and Mining Engineers. The firm operated also a chemical laboratory, and, locating at Chattanooga, Ten-

* Memoir prepared by James Nisbet Hazlehurst, M. Am. Soc. C. E.

nessee, soon established a satisfactory practice, numbering as clients several of the larger iron and coal companies of the region.

Mr. Guild resigned the State office in 1887, and at about the same time formed a new professional association—with Mr. Linn White—for the practice of civil and mining engineering, and engineering chemistry, under the firm name of Guild and White.

During this period of great activity and industrial development in and about Chattanooga, the young engineers executed most creditably many important commissions for the furnaces, mines, railways and development companies of the district.

During 1889, an important professional engagement was the design and construction of the Cameron Hill (Chattanooga) Passenger Incline Railway. Of similar character, but of far greater magnitude and importance, was the commission to build the passenger incline up Lookout Mountain, executed in 1894, and uniquely interesting in many engineering particulars, being in fact one of the longest and steepest inclines in the world. Its length was 5 000 ft., with an ascent of 1 700 ft., and with gradients of from 10 to 68 per cent. One of the most difficult problems, successfully solved, was the proper arrangement of the cableways along the sharp vertical curve where the railway location encountered the palisade or rocky escarpment, before reaching the Mt. Lookout plateau. The line is now in daily operation, and is well patronized.

The necessity of undertaking the completion of an abandoned contract, upon which the firm had inadvisedly become bondsmen, turned the attention of Guild and White to the possibilities of municipal contract work, and thereafter, for a number of years, the firm name was a familiar one at contract lettings throughout the Southern States, and was synonymous with unvarying integrity and engineering skill of high order. Scores of water-works and systems of sewers were completed successfully by them, and the record was fully maintained and augmented, when, at the retirement of Mr. White, in 1896, the title of the firm was changed to Guild and Company, Incorporated, Mr. J. C. Guild being the first executive officer.

The corporation prospered greatly, growing in financial strength and engineering reputation, Mr. Guild's individual earnings being largely invested in the commercial, manufacturing and financial undertakings of his home city, Chattanooga. To his conservatism, energy, foresight, and shrewd business acumen, the firm prosperity and highly organized character of these institutions bear abundant witness, and stamp with the sterling mark this Captain of Industry.

The crowning achievement of his busy brain was his conception of the commercial possibilities which might accrue through the utilization of the great power of the Tennessee River.

Originally a project of the Army engineers for the improvement of the river's navigation, the potentialities of a hydro-electric instal-

lation in connection therewith were first recognized and made possible through Mr. Guild's knowledge of its engineering features, his strong personality, directed toward securing city, state, and national legislation, and his ability to obtain the necessary capital for this great undertaking.

At the time of his death Mr. Guild was largely interested in the financial outcome, and occupied the position of Chief Engineer to the Chattanooga and Tennessee River Power Company. This immense work is at the present time under construction.

Had he accomplished nothing beyond this undertaking he would have left to posterity a fitting monument to his memory. Originally intended by the Government as remedial work to facilitate slack-water navigation, it was proposed in 1900 to construct, some 30 miles below Chattanooga, a dam of heavy timber cribs filled with stone, the deck to slope downward each way from the crest. A lock of cut-stone masonry was also to be provided, the estimated cost being $1 000 000.

As a subsidiary proposition, Mr. Guild's conception was the practical utilization of the water-power at this dam and its conversion into electrical energy. In addition to the legislative and financial difficulties to be overcome, there were at least two most unusual engineering or physical problems to be solved. First, the distance or height between the upper and lower pools could hardly be less at times than 50 ft., and was destined to be one of the highest single-lift locks in the world. The second difficulty and exceptional hydraulic condition to be met was caused by the most unusual variation in volume of flow and the resulting head upon the turbine wheels. To secure uniformity of speed and regular output under such conditions, three wheels are specified to each vertical shaft, the two lower turbines being fixed for the lower volumes, while the third wheel is intended to utilize great volumes at the lower head.

The lock, dam and power-house are of cyclopean concrete in continuous work. To convey some idea of the installation, it may be mentioned that the three cableways in operation span 2 300 ft., with vertical slack of 100 ft., constituting in themselves remarkable equipment features.

Such, in these poor words, are the activities and achievements of a lifetime.

Of splendid physique, clean and wholesome morals, a fascinating personality, and with a brilliant, trained and highly analytical mind, Josephus Conn Guild was called from Life's labors to enter into rest. He died on February 25th, 1907, in his home in Chattanooga, Tennessee, at the age of forty-five, in the prime of vigorous manhood, and at the height of his brilliant achievements.

Mr. Guild was elected a Member of the American Society of Civil Engineers on June 1st, 1898.

DUNKIN WIRGMAN HEMMING, M. Am. Soc. C. E.*

DIED MARCH 22D, 1906.

Dunkin Wirgman Hemming was born in Drummondville, Quebec, Canada, on November 10th, 1860, of a distinguished English Canadian family—his father, Edward J. Hemming, being a Queen's Counsel, and the first man to take the degree of Doctor of Civil Law at McGill University. He was named for an uncle, the Honorable Justice Dunkin, and another uncle was Senior Wrangler in mathematics at Cambridge University, England.

Mr. Hemming was educated at Bishop's College University, Canada. After graduation he studied law and was admitted to the Montreal Bar with high honors; he became associated with a prominent firm of criminal lawyers of Montreal, but gave up a promising career to avoid disagreement with his father, who disapproved of his connection with the criminal branch of legal practice.

He then turned his attention to Engineering, and, by his own unaided efforts, worked his way up to an enviable position as an engineer, and at the time of his death was without a superior, if he had an equal, in his special work as Contractor's Engineer.

In 1886 he entered the service of The Canadian Pacific Railway as Rodman, and was Transitman when he left that road, in 1889. His next engagement of length was as Assistant Engineer, and later as Resident Engineer, in charge of construction of the Baltimore Belt Railway, including the Baltimore and Ohio tunnel and extensive open work; he left this work in 1893, and, after a short engagement as Locating Engineer for The New York, New England and Northern Railway he came to New York City where practically all his subsequent work was done, the greater part of it as Contractor's Engineer with some of the strongest contracting firms and on the most important construction work in this vicinity, including such work as the construction of the Columbus Avenue and Lexington Avenue cable lines; the laying of many miles of gas mains and sewers; a part of the Park Avenue Improvements of the New York Central and Hudson River Railroad; the laying of pneumatic tubes connecting the New York Post-Office with Sub-Stations; putting in condensed air plants; laying water mains and changing sewers along the Rapid Transit Subway; piers for the Manhattan Bridge, 145th Street Bridge; Riverside Drive Extension, etc. In 1904 he became Engineer for one of the Contractors for the Rapid Transit Subway and the Jerome Park Reservoir, and was engaged in this work at the time of his last sickness.

He was married on June 4th, 1896, to Florence, eldest daughter

* Memoir prepared by Albert Carr, M. Am. Soc. C. E.

of Augustus W. Kriete, a wealthy and prominent citizen of Baltimore, and granddaughter of Judge Hugh Lennox Bond, of the old Maryland family of that name.

After about ten years of exceptionally happy married life he was attacked by an unexpected illness, which took him away at the time of his greatest usefulness, and after he had reached a position to reap the reward of his earlier labors.

A Canadian by birth, he became a naturalized citizen of the United States and a staunch American in ideals and beliefs, thoroughly loyal to the country which had afforded him wider opportunities than his native land.

Of a very companionable nature, and with the happy faculty of remembering people, he had a very large acquaintance in business and in the various organizations with which he was connected.

He was a member of the Franklin Institute, the Canadian Society of New York, and St. George's Society of New York.

He was elected an Associate Member of the American Society of Civil Engineers on September 7th, 1892, and a Member on May 31st, 1904.

JACOB HAYS LINVILLE, M. Am. Soc. C. E.*

DIED AUGUST 4TH, 1906.

Jacob Hays Linville, of Pennsylvania Quaker ancestry, was born on September 23d, 1825, on the farm of his father, Arthur Linville, near the little village of Pequea, Lancaster County, Pennsylvania. His father, besides farming, was also engaged as a tanner and currier, at Gap, Pennsylvania. His mother, also a Pennsylvanian, was Elizabeth Haines.

His primary education was obtained in the local public schools, and was followed by a course in the Academy of Dr. Duffield at Belleview, Lancaster County, Pennsylvania, where he was prepared for his college entrance examination. He was matriculated at Union College, Schenectady, New York, in September, 1845, at the age of twenty, and was graduated, with the degree of B. A., in July, 1848.

Nothing has been learned to indicate that he had any predilection for engineering as his future profession; in fact, shortly after his graduation, he engaged in teaching, in his home public schools, for a short term only, and then he seems to have decided to adopt the Law as his profession, and, with that in view, in 1851 or 1852, he entered, as a student, the law office of William M. Meredith, Attorney at Law, in Philadelphia. Evidently, however, he dis-

* Memoir prepared by Walter Katte, M. Am. Soc. C. E.

covered very soon that the Law was not his vocation, for he terminated his studies in it in less than a year.

Then, apparently, he determined to adopt Engineering, and his first employment was as a topographical assistant in the corps of engineers making the surveys for the Lancaster, Lebanon and Pine Grove Railroad, in his home county. This was followed by an engagement as Assistant Engineer in the corps of the late William Hasell Wilson, Hon. M. Am. Soc. C. E., then engaged upon the location and construction of the Philadelphia, Media and Westchester Railroad. In 1857 he was appointed Assistant Resident Engineer, under Mr. Wilson as Resident Engineer, on the Middle Division (Harrisburg to Altoona) of the Pennsylvania Railroad.

On May 21st, 1857, Mr. Linville married Miss Celeste Virginia Rush, daughter of a Philadelphia merchant. Their union was blessed with only one child, a son, named Samuel Rush Linville, who in later life adopted as his profession that of "Electrician;" he died in Philadelphia on May 12th, 1899, in his forty-first year.

In 1863 Mr. Linville was appointed Engineer of Bridges and Buildings for the Pennsylvania Railroad, with residence and office in Altoona, Pennsylvania, the general headquarters and offices of that company's Operating and Construction Departments. This appointment seems to mark a singularly interesting and important turning point in Mr. Linville's professional career, and is apparently the initial one from which started his subsequent brilliant achievements in the specialties of design and construction of railroad bridges and buildings, remarkable for the reason that, as far as can be learned, he started with very little, if any, technical training or practice in those specialties. That he fully realized this, is disclosed by the following extract from a letter written by him to a close personal friend many years later:

"I went to Altoona with a young wife, with everything new to me. The bridges on the line were nearly all a wreck; I knew nothing of bridges, and had at my disposal nothing but Haupt's old book, all wrong. Orders came in to build new iron bridges, and I had to hustle, with many sleepless nights, and days spent over old patterns and new plans and calculations involving many changes and improvements in the plans of the original cast-iron chord, arch, and posts of the old Pratt type."

In 1863-64, the Pennsylvania Railroad Company having determined to prosecute the construction of the old Pittsburg and Steubenville Railroad, the question of bridging the Monongahela River at Pittsburg, and the Ohio River at Steubenville, at once became of very serious moment, as it was most energetically and violently objected to by the united coal and boating interests of those rivers. It was alleged, and not without a good deal of plausibility, that any

piers placed in their boating channels would inevitably and utterly destroy their business, by rendering it impossible, or so dangerous as practically to make it impossible, to continue the old-fashioned "broadhorn" system of floating their coal to market, on which, to a great extent, it depended. This controversy was stubbornly maintained on both sides, and was fought with most virulent animosity, through no end of "Courts" and "Legislatures," until, finally, a compromise was arrived at when the Railroad Company agreed to construct, over the navigable channels of the rivers, spans of not less than 300 ft. in clear between the piers, on the water line.

The river interests believed that the railroad company would find it impracticable to design and erect a span of that length to sustain safely the then prevailing weight of railroad trains, as, at that time, it was pretty generally believed, even by many technical experts, that 250 ft. was about the safe limit of spans of bridging to sustain the railroad "live loads" of that day. However, the President of the Pennsylvania Railroad Company at that time—Mr. John Edgar Thomson—was far too astute, and too good an engineer himself, to have ever agreed to such terms, had he not previously assured himself of perfect ability to comply with them. He had been for some years well acquainted with Mr. Linville, and entertained a high opinion of his abilities as a bridge designer, and had accepted his assurance that it was practicable to design metallic spans, from 300 to 350 ft. in length, with entire safety.

Mr. Linville made only one reservation, namely, that the railroad company should cause to be built for him a testing machine sufficiently powerful to "test to failure" full-sized bridge members. Mr. Linville had satisfied himself—as indeed had many other engineers of that day—that the old formulas and experiments of Hodgkinson, Fairbairn, Kircaldy, *et al.*, could not be relied on to give absolutely safe standards of the ultimate strength and moduli of elasticity of full-sized members, as they were derived from the results of laboratory tests made upon samples of very small sectional area and length, and were entirely lacking in proof that the ratios would hold good when applied to the areas and lengths of full-sized members. Mr. Thomson, fully appreciating the value of this "proviso," at once gave Mr. Linville *carte blanche* to have Messrs. William Sellers and Company, of Philadelphia, build such a testing machine as would fulfill all his requirements. Such a machine was built by that firm, and was set up in the railroad company's shops at Altoona, and, in all probability, was the first testing machine ever built of sufficient power to demonstrate the actual limits of ultimate strength and elasticity of full-sized metallic members of framed structures.

With this machine Mr. Linville conducted a series of tests from

which he derived reliable data from which to assign the necessary safe sectional areas for the members of "long-span" structures. This machine, having thus filled the requirements for which it was specially built, was subsequently bought by the Keystone Bridge Company, and re-erected in that company's Pittsburg shops. It is probably still in the service of the successors of that company, the American Bridge Company, now merged into the United States Steel Company. Thus did this Steubenville span of 320 ft. become indeed the "pioneer" of long-span bridging in the United States, which fact is attested to in the following quotation from the admirable paper* on "American Railroad Bridges," by Theodore Cooper, M. Am. Soc. C. E.:

"The era of long span truss bridges in America may be considered as dating from the building of the first bridge over the Ohio River at Steubenville, between 1863-64, by Mr. J. H. Linville. The channel span was 320 feet long and 28 feet deep. The top chord and posts were made of cast-iron. It was proportioned for a rolling load of 3 000 pounds per foot of track, a notable increase in the load heretofore in use."

In the latter part of 1864, Mr. Andrew Carnegie procured the incorporation, under the laws of Pennsylvania, of the Keystone Bridge Company, to take over the shops and business of the bridge building firm of Piper and Shiffler, of Pittsburg, at that time engaged principally in manufacturing and erecting the reconstructed bridges of the Pennsylvania Railroad upon the plans and specifications of Mr. Linville. This new company was organized with Mr. Linville as President and Consulting Engineer; John L. Piper, General Manager; Aaron G. Shiffler, Treasurer and General Superintendent, and Walter Katte, Secretary and Engineer of Shops and Erection.

Ample new capital being subscribed, the business scope and shop manufacturing facilities were at once largely augmented, resulting in this company speedily taking prominent rank among the leading bridge building organizations of the country. To this company the Pennsylvania Railroad Company awarded the contract for the manufacture and erection of the superstructures of the Steubenville and Monongahela Bridges, upon the plans and specifications previously prepared by Mr. Linville and accepted by the railroad company. The successful execution of this order, and the experience gained therefrom, so qualified this company and established its reputation as builders of long-span metallic bridges, that it at once entered the field as a very active competitor in the many bridging projects of the great western rivers, then being promulgated, all requiring exceptionally long spans. To this company were subsequently awarded the contracts for the manufacture and erection

* *Transactions*, Am. Soc. C. E., Vol. XXI, p. 1.

of the superstructures of the following notable long-span bridges, all of which were designed by Mr. Linville:

Monongahela River, Pennsylvania Railroad, at Pittsburg, Pa.;

Ohio River, Baltimore and Ohio Railroad, at Bellaire, Ohio;

Ohio River, Baltimore and Ohio Railroad, at Parkersburg, W. Va.;

Ohio River, Cincinnati and Newport Railroad, at Cincinnati, Ohio;

Ohio River, Cincinnati Southern Railroad, at Cincinnati, Ohio;

Missouri River, Draw Span, Hannibal and St. Joseph Railroad, at Kansas City, Mo.;

Mississippi River, Illinois Central Railroad, at Dubuque, Iowa;

Mississippi River, Keokuk and Hamilton Bridge Company, at Keokuk, Iowa;

Mississippi River, Draw Span, Chicago and Alton Railroad, at Louisiana, Mo.

The shop detailed working drawings of the great steel arch bridge over the Mississippi River at St. Louis, designed by the late James B. Eads, M. Am. Soc. C. E., and manufactured and erected by the Keystone Bridge Company, were also reviewed and revised personally by Mr. Linville in order to insure the successful erection of that great and novel structure, upon the cantilever suspension system, for which the Keystone Bridge Company was under contract responsibility.

During his service as Engineer of Bridges and Buildings of the Pennsylvania Railroad Company, Mr. Linville designed and supervised the erection of the new wrought-iron bridges over the Schuylkill River, at the Arsenal, Philadelphia, on the Delaware River extension of the Pennsylvania Railroad. This was the first bridge built with wrought-iron posts, and "upset" head-link tension members, and, by its use of hollow wrought-iron columns, started the long legal contest between the Phœnix Iron Company and the Keystone Bridge Company *et al.*, for alleged infringement of its patent rights. This was finally decided by Justice McKenna, in the United States District Court of Pittsburg, in favor of the defendant parties.

At about this time Mr. Linville resigned from the service of the Pennsylvania Railroad Company, and removed to Philadelphia where he opened an office for private practice as Consulting and Designing Civil Engineer. He was immediately commissioned by the Pennsylvania Railroad Company to prepare plans and specifications for the reconstruction in metal of many of its most important bridge structures, among which may be specially noted the following: "Dauphin Bridge," Susquehanna River, on the Northern Central Railroad; and the "Maryland's Creek" and "Ridley's

Creek" Bridges, on the Media and Westchester Railroad. He was also commissioned by the Lehigh and Delaware Railroad Company to prepare plans and specifications for the bridging of its line, including notable structures over the Delaware and Lehigh Rivers at Easton, Pennsylvania; and also by the Central Railroad Company of New Jersey for its long-span pivot draw-spans at Amboy and Newark, New Jersey.

In addition to his high attainments as a bridge designer, Mr. Linville developed marked skill as an architect, notably in the specialty of industrial buildings. Having a finely cultivated artistic taste, his designs for such buildings, while skillfully adapted to the technical requirements, were always architecturally attractive in their treatment. He was commissioned by the Pennsylvania Steel Company as its Chief Engineer during its constructive period, 1863-65, and designed and supervised the erection of all its shops and buildings at Steelton, Pennsylvania. For the Pennsylvania and the Philadelphia and Erie Railroad Companies he designed the shops at West Philadelphia, Harrisburg, Sunbury, Renovo, and Kane; also those at Uhrichsville for the Pittsburg, Cincinnati and St. Louis Railroad Company, and the new shops for William Sellers and Company, in Philadelphia.

In the early days of elevated railroad projecting Mr. Linville was consulted by Dr. Gilbert (one of the original promotors of elevated railway projects) to revise and perfect his plans, which resulted in his designing the structure which was subsequently manufactured and erected for the Metropolitan Elevated Railroad Company (afterward the Manhattan Elevated Railway Company) on its Sixth Avenue line, between Canal and Fifty-ninth Streets, New York City.

In 1876 Mr. Linville made a notable exhibit of engineering drawings and models at the Philadelphia Centennial Exposition, for which he was highly commended, and received a bronze medal.

About the year 1880 Mr. Linville and A. P. Boller, M. Am. Soc. C. E., were selected by the Pennsylvania Railroad Company to act as arbitrators in the settlement of a controversy between that company and the Long Branch Railroad Company. Subsequent to this Mr. Linville was induced to assume the Presidency of a railroad company which had failed in its efforts to complete a railroad in the southwesterly peninsula of Maryland. He took hold of this moribund enterprise, and by his untiring energy was successful in clearing off all its old debts and judgments; he called in and cancelled all its old stock and bond liabilities, issued new stock, and effected a contract with a Boston syndicate to complete the construction and equipment of the road. His efforts in this field, however, were finally frustrated by the failure of the financial promotors of the enterprise to support it.

In the latter days of his professional life, Mr. Linville was induced, by parties owning patents on an electro-magnetic printing telegraph device, to undertake to perfect their machine, as hitherto they had failed to make it work satisfactorily. He became most enthusiastically interested in it, and worked over it with such energy, that, in the end, his health was seriously affected, but finally he succeeded in perfecting the apparatus. It is claimed that his was the first machine, of this type of electrical telegraphic devices, that worked perfectly. In the end, however, it was a great loss and disappointment to him, owing to the failure of the promoting company to finance the enterprise adequately.

For many years prior to his death, Mr. Linville was a most acute sufferer from chronic catarrhal bronchitis and neuralgia of the head, which affected his eyes. Toward the end, his sufferings from these causes became so intense that he was compelled to give up his professional practice. Personally, his disposition was singularly loving and sympathetic, and all with whom he came in contact were greatly attached to him.

Mr. Linville was elected a Member of the American Society of Civil Engineers on March 3d, 1875.

GEORGE BENSON NICHOLSON, M. Am. Soc. C. E.*

DIED DECEMBER 2D, 1906.

George Benson Nicholson was born in Cheltenham, England, on September 24th, 1840. His father, John Nicholson, was an Irishman of English descent, and his mother, Matilda Jane Williams, was Irish by birth but Welsh and English by descent.

The family came to America in 1842, and after a short time located in Cincinnati, Ohio.

The father died in 1852, and the care and support of the family thereafter devolved upon George, the only son, and his sisters. Under these circumstances, there was not much time or opportunity for the boy to obtain a school education, and this was limited to the common schools, and one year in the high school of Cincinnati. But, all his life, he was a close student, and an extensive and discriminating reader, and thus largely made up the deficiencies in his early education. As illustrating this, it may be mentioned that he was familiar with the classics of his own tongue, mastered the French language, and was considered an authority upon heraldry —a specialty of which he was particularly fond.

* Memoir prepared by Samuel Whinery, M. Am. Soc. C. E.

He began the serious business of life at the age of sixteen, when he entered the office of the late A. W. Gilbert, at that time one of the leading engineers of Cincinnati, and thus commenced the special work and studies which were to lead to his professional career.

When the Civil War came on, young Nicholson was one of the earliest to volunteer as a soldier in the Union cause. He enlisted on April 22d, 1861, in Company K, Sixth Ohio Volunteer Infantry (widely known as the Guthrie Greys), and on June 18th he was enrolled in that regiment for three years, and served until the expiration of his term.

Of his career as a soldier, the following endorsement on his discharge papers affords a brief but eloquent record:

"HEADQUARTERS Co. K.,
"6TH REG., O. V. I.
"June 23rd, 1864.

"First Sergeant G. B. Nicholson deserves more than an ordinary notice of the meritorious service he performed during his term of enlistment. Although but a mere youth when he enlisted, he bore the fatigues of the arduous campaigns participated in by his regiment in West Virginia, Kentucky, Tennessee, Mississippi, Alabama and Georgia, with a degree of fortitude seldom found in one of his age and physique. He was ever a brave, intelligent, uncomplaining soldier, and behaved with more than ordinary gallantry in the engagements of Carrick's Ford (July, '61), Shiloh, Stone River, Chickamauga and Missionary Ridge. At the battle of Stone River he received a desperate wound, from which it was feared he would not recover; but his wonderful courage and determination carried him through. I deem this tribute the just due of one whom it was an honor to command, and whom I consider the beau-ideal of an American volunteer soldier.

"(Signed) J. M. DONOVAN,
"Capt. Co. K, 6th O. V. I."

His patriotic duty having thus been discharged, he again turned his attention to the profession he had chosen for his life work.

For a year he was engaged as Assistant Engineer in the military service of the Government, Department of Kentucky; then, for a short time, he was Mechanical Draftsman in the office of a patent attorney in Cincinnati. This was followed by 6 months' service as Assistant Engineer on street railroad construction in the same city. In March, 1866, he went to what was then the wilds of Montana and Idaho to locate and construct the Lewiston and Virginia City wagon roads, one of which he located through the Bitter Root Range of the Rocky Mountains; but, owing to inadequacy of funds, little construction work was done.

Returning to Cincinnati in March, 1867, he entered the service of the city as Engineer in Charge of Sewers, but in October of the

same year he gave up this work to re-enter the Government service as United States Assistant Engineer on the improvement of the Mississippi and the Missouri Rivers.

Early in 1869 he became Assistant Engineer of the Fifth Light-house District, and spent two years in charge of the construction and repair of light-houses, wharves, etc., along the coasts of Maryland, Virginia, and North Carolina.

From February, 1871, to February, 1872, he was Shop Inspector, for the Government, of the ironwork for the Rock Island Bridge. He then returned to the Light-house service, in the Eighth Light-house District (coast of the Gulf of Mexico), where he had charge of the design, construction, and repair of light-houses, keepers' dwellings, beacons, breakwaters, and other work incidental to the position, and the making of several hydrographic surveys.

On July 4th, 1873, he entered upon the work that was chiefly to occupy the remainder of his life—the location, construction, and engineering maintenance of the Cincinnati Southern Railway and its associated roads. At first he was engaged upon the surveys for the location of the Ohio River Bridge and its approaches at Cincinnati.

Then, in June, 1874, he became Division Engineer in direct charge of the construction of the first 40 miles south of Cincinnati, involving a large amount of difficult and expensive work. As the construction work on other divisions to the southward approached completion, Mr. Nicholson's jurisdiction was extended over them, and, for several years, after November, 1876, he had charge of the engineering work of the northern 160 miles of the road, under the late L. F. G. Bouscaren, M. Am. Soc. C. E., Chief Engineer.

The building of the Cincinnati Southern Railway was one of the notable public works of that period, and marked many substantial advances in railroad engineering. The Ohio River Bridge contained the longest truss-span attempted up to that time, and the Kentucky River Bridge was not only the highest railroad bridge in the world, but was the first cantilever bridge in America. The designs and specifications for the bridges for this road mark an epoch in the progress of bridge building. The road was a difficult and expensive project. The stretch from the Cumberland River to the Emory River, crossing the Cumberland Mountain, was probably the heaviest and most expensive one hundred consecutive miles of railroad ever built in America. There were twenty-one tunnels within the limits named. The construction work was begun under the late Thomas D. Lovett, M. Am. Soc. C. E., as Chief Engineer, with the late L. F. G. Bouscaren as first Assistant. When Mr. Lovett retired, Mr. Bouscaren succeeded him, concentrating upon the work his unflagging energy and his brilliant mind. The

work afforded a valuable school of experience for the younger men engaged upon it, several of whom, in addition to Mr. Nicholson, have since become well known in the profession.

In 1880 the lessees of the Cincinnati Southern Railway and the Alabama Great Southern Railroad, decided to build the New Orleans and North Eastern Railroad from Meridian, Mississippi, to New Orleans, Louisiana, and Mr. Nicholson, under Mr. Bouscaren, Chief Engineer, was placed in charge of the location and construction of the southern half, from New Orleans northward for about a hundred miles, and to this work he devoted the next four years. The longest railroad trestle bridge then in existence, 26 miles, carrying the road over Lake Pontchartrain and its marshes, was built under Mr. Nicholson's immediate charge. This short line of road involved other difficult and troublesome work quite out of proportion to the magnitude of the enterprise.

In 1885 Mr. Nicholson succeeded Mr. Bouscaren as Chief Engineer of the Cincinnati Southern and Associated roads, known then as the Queen and Crescent System. While changes in organization and in the constituent roads, which make up the present Queen and Crescent System, took place in the meantime, Mr. Nicholson continued to be its Chief Engineer until his death, retaining the unbounded confidence and friendship of every management. It is currently believed that during this time he was more than once offered promotion to higher executive departments, but no official confirmation of the fact is at hand, and Mr. Nicholson's extreme modesty prevented him from discussing such matters even with his intimate friends. It is known that outside positions, involving high honor and attractive compensation, were offered to him during this period, but he remained loyal to the road to which his services had become almost indispensable. Having been connected with the system since its inception, he knew every engineering and historical detail of its construction and operation, and could therefore serve the management far more efficiently than any new man who might be called to take his place.

His services, however, were not confined to the roads of which he had official charge. He was one of the trusted lieutenants of the late Samuel Spencer, President of the Southern Railway, of which the Cincinnati, New Orleans and Texas Pacific Railway is a part, and he was frequently called upon confidentially to examine and report upon important matters outside of his official jurisdiction.

To these, as well as to his own legitimate work, he applied and spent himself without reserve, and with little regard for his physical and mental welfare. Like others of his intense and conscientious temperament, he devoted his personal attention to many details which he might more wisely have referred to his assistants,

who were able and loyal. The late night, as well as the day, usually found him at his desk. The result was the too frequent one. The constitution that had carried him safely through the hardships and the physical stress of an unusually strenuous service in the Army, finally gave way under the later and greater mental and physical strain, and he found himself face to face with a nervous collapse. Early in 1906, against his will, he was directed by his superior officers to take a vacation. Returning from this, not much improved in health, his leave of absence was extended indefinitely, and he was persuaded to go abroad on full pay, with the hope that his health might be restored. This hope was not realized. His health continued to decline, and, returning late in November, 1906, he survived but a short time, dying on December 2d, 1906, in the home in Covington, Kentucky, he had so long occupied.

Of Mr. Nicholson's personal character and professional ability and attainments, it may be said that against his honor and integrity there was never a breath of suspicion. Considering the fact that his ordinary educational advantages were very limited, and that of technical school education and training he had none, his knowledge of the technical side of engineering was quite remarkable; but he was most noted for his sound practical sense and good judgment —the result of an able and alert mind backed by a wide experience. To his extreme modesty, amounting almost to shyness, in professional as well as in social affairs, must be attributed the fact that he appeard but seldom in the public eye.

No memoir of Mr. Nicholson, however brief, would be complete without some reference to his connection with "The Literary Club," of Cincinnati. This organization, founded in 1849, has been a notable center of literary culture in that city. Its membership list at any period, since its organization, has embraced the leading public, professional and literary men of the city and the surrounding region. In this list, past or present, may be found the names of one President of the United States, nine Generals of prominence in the United States Army, two United States Senators, three Governors of Ohio, seven Members of Congress, one Chief Justice of the United States, one distinguished actor, no less than three well-known poets, one Minister to Russia, and the present very able and honored Secretary of War.

Its meetings, held every Saturday night, when a paper is read, followed by a modest collation and an hour of social intercourse, may, without exaggeration, be characterized by the phrase, "A feast of reason and a flow of soul."

Mr. Nicholson became a member of this organization in 1885, and thereafter, until his death, was one of its most devoted and

useful members, serving as its President for two years, and for many years in other official capacities. In the cultured bonhomie of this club he found a congenial atmosphere in which the fine qualities of his mind and heart expanded into full flower. Next to his family and his work, this club and its interests occupied a front place in his mind and activities during the later part of his life. It is stated that "He contributed some twenty papers to the club, every one being a paper of merit." It was principally through his efforts that all the published works, numbering between 300 and 400, of those whose names appear on the membership list of the club since its organization, were collected into the club library.

The verdict of such a body of men as compose the membership of this club, upon the personal character and worth of Mr. Nicholson may be accepted as conclusive. The minute adopted by the club in his memory is, therefore, here in part quoted:

"His chief characteristics were integrity, a high sense of honor, modesty and unselfishness; the latter manifesting itself in a kindly interest, not only in people, but in the lower animals. If he encountered a tramp dog lying shivering on a cellar door, he would go out of his way to a chop house, buy food and carry it to the suffering creature.

"Everything he undertook to do he did well, he neglected nothing; and the only reward he valued was the consciousness of duty fulfilled and honor cherished. He had no itching greed for wealth nor social prominence, but enjoyed the amenities of life with his groups of friends with hearty good will. Owing to his devotion to his mother and sisters, and the children of one sister who was left in middle life with a dependent family, he never married.

"No one of us ever heard him refer to his military service, nor to any of the great achievements of his life. His modesty forbade; but he preserved all the records of his career as the safeguards of his honor. He felt, with Norfolk:

> " 'Mine honor is my life;
> Both grow in one;
> Take honor from me,
> And my life is done.'

"The exquisite charm of his friendship can be known only to those who enjoyed it; to them it was a benediction, and his death an irreparable loss."

Others who had the honor and pleasure to be numbered among his more intimate friends will fully endorse this estimate of his character.

Mr. Nicholson was elected a Member of the American Society of Civil Engineers on May 1st, 1878, took a keen interest in its affairs, and occasionally contributed to the discussion of papers read before it.

MERRITT HARRISON ROGERS, M. Am. Soc. C. E.*

DIED MAY 3D, 1907.

Merritt Harrison Rogers was born on May 19th, 1851, at Center Moreland, Pennsylvania, of one of the oldest New England families, his ancestors having been among the first settlers in Salem, Massachusetts.

He was educated at New Columbus Academy and Wyoming Seminary.

Mr. Rogers took part in the location and construction of several railroads in Pennsylvania, and in 1878 entered the service of the Kansas Pacific Railroad. In 1880 he became Transitman on the Denver and Rio Grande Railroad, and was appointed Assistant Engineer of that road in 1881 and Division Engineer in 1883, which position he held for six years. At that time the office of Chief Engineer was abolished, and Mr. Rogers was made Resident Engineer, with the duties and powers of Chief Engineer. Many extensions and improvements were made during this time.

In 1890, the office of Chief Engineer was revived, and Mr. Rogers was appointed to that position. In 1892 the superintendency of bridges and buildings was added to his duties.

In 1902 he retired and became a Consulting Engineer. At the end of two years he went to California for his health, and remained there a year. He returned to Colorado about a year ago and was appointed Chief Engineer of the Denver and Transcontinental Railroad. While going into the field to start a locating party for the season, he was stricken with apoplexy and died.

Mr. Rogers possessed the sterling qualities of his New England ancestors. He was of a high personal character, devoted to his friends and to his profession. He was an engineer of ability, and did much to develop the railroads of the West.

About twenty-two years ago he married Miss Mattie Dodge, of Buffalo, New York, who survives him. They had two children, but both died in infancy.

Mr. Rogers was elected a Member of the American Society of Civil Engineers on January 2d, 1890.

* Memoir prepared by J. W. Deen, M. Am. Soc. C. E.

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NEW YORK 1907.

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American Society of Civil Engineers.

OFFICERS FOR 1907

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BERNARD R. GREEN.

Term expires January, 1909:
JOHN A. BENSEL,
JOHN A. OCKERSON.

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MORRIS R. SHERRERD,
HEZEKIAH BISSELL,
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Term expires January, 1909:
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ON STATUS OF METRIC SYSTEM:—Stacy B. Opdyke, Jr., John Waterhouse, D. A. Molitor.

ON ENGINEERING EDUCATION:—Desmond FitzGerald, Benjamin M. Harrod, Onward Bates, D. W. Mead, Charles Hansel.

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER.....5913 Columbus.
CABLE ADDRESS....."Ceas, New York."

Vol. XXXIII. SEPTEMBER, 1907. No. 7.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

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MINUTES OF MEETINGS.

OF THE SOCIETY.

September 4th, 1907.—The meeting was called to order at 8.30 P. M.; Director A. L. Bowman, in the chair; Chas. Warren Hunt, Secretary; and present, also, 106 members and 12 guests.

The minutes of the meetings of May 15th and June 5th, 1907, and those held at the Thirty-ninth Annual Convention in Mexico, July 8th, 9th and 10th, 1907, were adopted as printed in *Proceedings*.

A paper entitled "Comparison of Rainfall and Run-Off in the Northeastern United States," by John C. Hoyt, Assoc. M. Am. Soc. C. E., was presented by the author.

The Secretary presented written discussions by E. C. Murphy, Assoc. M. Am. Soc. C. E., and Charles A. Holden, Assoc. Am. Soc. C. E., and the subject was further discussed by Professor Alfred J. Henry, of the U. S. Weather Bureau, and by Messrs. H. von Schon, Thaddeus Merriman, H. K. Barrows, and the author.

Ballots for membership were canvassed, and the following candidates elected:

As Associate Members.

George Hill Banks, Houghton, Mich.
John William Eber, New York City
Milo Stuart MacDiarmid, Detroit, Mich.
Frederick Gardiner Skinner, Bethlehem, Pa.

The Secretary announced:

The transfer of the following candidates by the Board of Direction:

From Associate to Associate Member.

On June 4th, 1907:

Augustus Valentine Saph, Berkeley, Cal.

From Associate Member to Member.

On September 3d, 1907:

James Churchill Boyd, New York City
William Hale Ham, Youngstown, Ohio
John Thomas Henderson, Hartford, Conn.
Robert Austen McCulloch, New York City
William Sutton McFetridge, LaGrange, Me.
Henry Wray Preston, Elmira, N. Y.
William Jackson Roberts, Pullman, Wash.

The election of the following candidates by the Board of Direction:

As Juniors.

On February 5th, 1907:

Charles Ray Hawley, Honey Grove, Tex.
Leo Charles O'Byrne, Chicago, Ill.
John Lynch O'Hearn, Clinton, Okla.

On March 5th, 1907:

William Franklin Martin, Los Angeles, Cal.

On April 30th, 1907:

William Bartlett Atwood, Lima, Ohio
Daniel Everett Bellows, Little Falls, N. Y.
Robert Walter Wood, West New Brighton, N. Y.

On June 4th, 1907:

Farrand Northrop Benedict, Long Island City, N. Y.
Paul Delmont Bunker, Key West Barracks, Fla.

HARRY CHITTENDEN VENSANO, San Francisco, Cal.
JOHN ROBERT WILBANKS, St. Louis, Mo.
ALBERT JONES WILLIS, South Bethlehem, Pa.

On September 3d, 1907:

WILLARD SEYMOUR BREWER, Hartford, Conn.
GEORGE WILLIAM BURPEE, Brockton, Mass.
LESTER LEVI CARTER, Vallecito, Cal.
ALDEN BRIGHAM COLE, Carbondale, Pa.
HERBERT BISMARCK FOSTER, Berkeley, Cal.
JAMES AUGUSTINE GALVIN, Mechanicsville, N. Y.
THOMAS MACLENATHEN GOODRICH, Brooklyn, N. Y.
JOHN PATRICK HURLEY, Mechanicsville, N. Y.
HAROLD LORD, Honolulu, Hawaii.
ADELBERT PHILO MILLS, Ann Arbor, Mich.
WILLIAM WATTERS PAGON, Baltimore, Md.
BIRTRAM WILLARD RANSON, Boston, Mass.
WILDER MELOY RICH, Grand Rapids, Mich.
GEORGE CORLISS SEE, Gloversville, N. Y.
HARRY SHOEMAKER, Fort Edward, N. Y.
MULFORD STOW, Troy, N. Y.
ALFRED LOCKWOOD TROWBRIDGE, San Francisco, Cal.

The Secretary announced the following deaths:

ALBERT JOHNSTONE CAMPBELL, elected Associate Member, May 2d, 1894; died June, 1907.

MONTAGUE SYLVESTER HASIE, elected Member, February 3d, 1897; died May 30th, 1907.

GALEN W. PEARSONS, elected Member, January 6th, 1875; died August 19th, 1907.

CHARLES FRANCIS POWELL, elected Member, October 3d, 1888; died July 30th, 1907.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract)

September 3d, 1907.—President Benzenberg in the Chair; Chas. Warren Hunt, Secretary, and present, also, Messrs. Bowman, Gibbs, Knap, Noble, Schneider, Sherrerd, Smith, and Tillson.

The report of the Nominating Committee was received.

A committee to recommend the award of prizes for the year ending with the *Transactions* for July, 1907, was appointed.

Applications were considered, and other routine business transacted.

Seven Associate Members were transferred to the grade of Member, and seventeen candidates were elected as Juniors.

Adjourned.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, October 2d, 1907.—8.30 P. M.—Ballots for membership will be canvassed, and two papers will be presented for discussion, as follows: "Reinforced Concrete Towers," by D. W. Krellwitz, Jun. Am. Soc. C. E.; and "Reinforced Concrete Pipe for Carrying Water Under Pressure," by Chester Wason Smith, Assoc. M. Am. Soc. C. E.

These papers were printed in *Proceedings* for August, 1907.

Wednesday, October 16th, 1907.—8.30 P. M.—At this meeting a paper entitled "The Bracing of Trenches and Tunnels, With Practical Formulas for Earth Pressures," by J. C. Meem, M. Am. Soc. C. E., will be presented for discussion.

This paper was printed in *Proceedings* for August, 1907.

Wednesday, November 6th, 1907.—8.30 P. M.—Ballots for membership will be canvassed, and a paper entitled "Water Purification at St. Louis, Mo.," by Edward E. Wall, M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings*.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all meetings:

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Society of Engineers, 17 Victoria Street, Westminster, S. W., England.

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Civil Engineers' Club of Cleveland, 718 Caxton Building, Cleveland, Ohio.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa.

Engineers' Society of Western Pennsylvania, 803 Fulton Building, Pittsburg, Pa.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

Louisiana Engineering Society, 604 Tulane-Newcomb Building, New Orleans, La.

Engineers' Club of Central Pennsylvania, Corner Second and Walnut Streets, Harrisburg, Pa.

Engineers' and Architects' Club of Louisville, Ky., 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

Teknisk Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Société des Ingénieurs Civils de France, 19 Rue Blanche, Paris, France.

Svenska Teknologförenigen, Brunkebergstorg 18, Stockholm, Sweden.

Institute of Marine Engineers, 58 Romford Road, Stratford, London, E., England.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Pacific Northwest Society of Engineers, 617–618 Pioneer Building, Seattle, Wash.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Memphis Engineering Society, Memphis, Tenn.

Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

The Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Institution of Engineers of the River Plate, Buenos Aires, Argentine Republic.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Cleveland Institute of Engineers, Middlesbrough, England.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Rochester Engineering Society, Rochester, N. Y.

Brooklyn Engineers' Club, 197 Montague Street, Brooklyn, N. Y.

Montana Society of Engineers, Butte, Montana.

SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

In reference to this work, the Appendix* to the Annual Report of the Board of Direction for the year ending December 31st, 1906, contains a summary of all searches made to that date.

* *Proceedings*, Vol. XXXIII, p. 20 (January, 1907).

ACCESSIONS TO THE LIBRARY.

(From August 8th to September 10th, 1907.)

DONATIONS.*

SHAFT-SINKING UNDER DIFFICULT CONDITIONS.

By J. Riemer. Translated from the German by C. R. Corning and Robert Peele. Cloth, 9 x 6 in., illus., 13 + 176 pp. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1907. $3.00.

Various papers, dealing with this subject, have been issued from time to time by German mining engineers. These papers are brief and intended only for those who make a specialty of shaft-sinking. The author states that, for this book, he has revised and amplified these articles so as to adapt them to the use of mining engineers and students of mining engineering generally. The only methods explained at length are those which deal with shaft-sinking under difficult conditions. The method of sinking by hand is first discussed. This is followed by detailed descriptions of the boring system, the freezing process and drop-shafts, together with illustrated examples of each method. In the translators' preface it is stated that, while the subjects dealt with have been rather outside the practice of American mining engineers, on account of the more favorable conditions obtaining in this country, yet some of the methods of sinking described by the author, or an adaptation of them, are applicable and may be used by civil engineers in building deep foundations for heavy structures in watery soils. The Contents are: Shaft-Sinking by Hand; Shaft-Sinking by the Boring System; The Freezing Process; Drop-Shafts. There are nineteen plates and an index of two pages.

OPEN-HEARTH STEEL CASTINGS.

By W. M. Carr. Cloth, 8 x 5½ in., illus., 118 pp. Cleveland, Ohio, The Penton Publishing Company, 1907. $1.50.

On the title-page of this book, it is stated that it has been compiled from a series of articles written for and published by *The Iron Trade Review* and *The Foundry*. It is also explained that it is a complete exposition of the methods involved in the manufacture of open-hearth steel castings by the basic and acid processes. The Chapter headings are: Melting Stock for Acid Practice, Fuels and Alloys, Molding Materials, Materials for Basic Practice; Open-Hearth Furnace Construction; Fuels and Accessories; Manipulation of Heats in Acid Practice; Manipulation of Heats in Basic Practice, Order of Charging, Melting, Charging Cold Stock; Chemical Analyses and Physical Tests; Relation Between Composition and Physical Properties; Blow Holes in Steel Castings; Discussion of the Causes of Cracks in Steel Castings; Heat Treatment and Annealing; Repair of Steel Castings with Thermit; Cost of Equipment for Open-Hearth Steel Foundries. There is no index.

DESIGN AND CONSTRUCTION OF HYDRO-ELECTRIC PLANTS,

Including a Special Treatment of the Design of Dams. By R. C. Beardsley. Cloth, 9½ x 6½ in., illus., 7 + 512 pp. New York, McGraw Publishing Company, 1907. $5 net.

The subject is presented by the author in the order in which the various problems connected with the development of a complete water-power plant would be considered and studied by the practical engineer. These problems are discussed in detail, and cost items and data are included, which make the book valuable to teachers and students as well as to engineers and contractors. The principles of hydraulics are briefly explained in the first chapter, followed by a discussion on the measurement of the flow of water over weirs, dams, etc. Useful curves are included in this chapter with examples as to their use. The remainder of the book is devoted to a study of water-power plants, beginning with the preliminary investigations which should be made by the engineer as to the power of streams; a discussion of the suitability of various materials to be used in hydraulic construction follows, together with descriptions of methods and machinery used in such work. The design and construction of dams are discussed, together with the design and construction of power houses. Illustrations are given of well-known power plants, with designs for special conditions. Power-house equipment and the transmission of power are discussed in detail, and full descriptions of apparatus used in modern

*Unless otherwise specified, books in this list have been donated by the publisher.

practice are included. The book concludes with a chapter containing tables and formulas giving the power and energy of water under different conditions, etc. Many illustrations and tables are included, and there is an index of ten pages. The Contents are: Hydraulic Principles; Measurement of Flow; Reconnaissance of Water Power; Materials; Hydraulic Construction; Power House Construction; Power House Equipment; Power Transmission; Tables and Formulæ.

A TREATISE ON HIGHWAY CONSTRUCTION.

By Austin T. Byrne. Ed. 5, Rev. and Enl. Cloth, 9 x 6 in., illus., 43 + 1040 pp. New York, John Wiley & Sons, 1907. $5.00.

As stated in the secondary title, this book is designed for all who may be engaged in the location, construction, or maintenance of roads, streets and pavements. In the preface to this edition it is stated that considerable new matter has been added, enlarging the book by some 120 pages. The new matter consists of improved methods for testing paving materials; effects of motor vehicles on roads; results of experiments for the suppression of dust; use of asphaltic oil for the improvement of earth roads; and suggestions for the construction of roads adapted to modern traffic. There are added also statistics of capital invested in street pavements in the principal cities of the United States, with the *per capita* cost of maintenance. The Chapter headings are: Pavements; Materials Employed in the Construction of Pavements; Stone Pavements; Wood Pavements; Asphaltum and Coal-Tar Pavements; Brick Pavements; Broken-Stone Pavements; Miscellaneous Pavements; Foundations; Resistance to Traction; Location of Country Roads; Width and Transverse Contour; Earthwork; Drainage and Culverts; Bridges, Retaining-Walls, Protection Works, Tunnels, Fencing; City Streets; Footpaths, Curbs, Gutters; Reconstruction and Improvement of Country Roads; Maintenance, Repairing, Cleansing, and Watering; Trees; Staking out the Work; Specifications and Contracts; Implements and Prices; Miscellaneous Notes. There are four Appendices: Naming and Numbering Country Roads and Houses; Methods of Assessing the Cost of Street Paving; Ordinance Regulating the Width of Wagon-Tires; Cycle-paths; and an index of ninety-three pages.

Gifts have also been received from the following:

Aachen Kgl. Technische Hochschule. 1 pam.
Ala.-Chf. Mine Inspector. 1 pam.
Am. Foundrymen's Assoc. 1 pam.
Am. Inst. of Archts. 1 vol.
Berlin Kgl. Technische Hochschule. 1 pam.
Blanchard, A. H. 1 bound vol.
Brit. Fire Prevention Committee. 19 bound vol.
Buffalo, Rochester & Pittsburgh Ry. Co. 1 pam.
Cape of Good Hope-Colonial Secretary's Office. 3 pam.
Casares, David. 1 pam.
Central of Georgia Ry. Co. 1 pam.
Chanute, Octave. 1 pam.
Cincinnati, Ohio-Water Dept. 1 pam.
Conn.-State Highway Commr. 1 bound vol., 1 vol.
Corthell, E. L. 1 pam.
Eng. Soc., State Univ. of Iowa. 1 pam.
Eng. Soc., Univ. of Mich. 1 pam.
Fowler, C. E. 1 pam.
Glasgow, Scotland-Corporation Tramways. 1 pam.
Hannover Kgl. Technische Hochschule. 1 pam.
Hill, J. W. 1 pam.
India-Ry. Board. 1 pam.
Iron and Steel Inst. 1 bound vol., 1 vol.
Kimberly, A. E. 1 pam.
Lehigh Valley R. R. Co. 1 pam.
Long, Thos. J., Bequest. 75 bound vol., 5 vol., 186 pam., 52 specif., 3 maps and drawings, 3 blue prints.
Lynn, Mass.-Public Water Board. 1 pam.
McKeesport, Pa.-Board of Water and Lighting Comm. 1 pam.
Madras Presidency-Public Works Dept. 1 bound vol.
Manchester Steam Users' Assoc. 1 pam.
Marlborough, Mass.-Board of Water Commrs. 1 pam.
Mass.-Charles River Basin Comm. 1 pam.
Matamoros, L. 1 pam.
Michigan-State Board of Health. 1 bound vol.
Midland Ry. Co. 1 pam.
Minnesota R. R. and Warehouse Comm. 1 bound vol.
National Board of Fire Underwriters. 1 pam.
New Jersey-State Board of Health. 1 bound vol.
New South Wales-Govt. Statistician. 3 pam.
New South Wales-Met. Board of Water Supply and Sewerage. 1 bound vol.
New York City-Board of Water Supply. 2 vol.
New York City-Bureau of Buildings, Borough of Manhattan. 1 bound vol.
New York-State Engr. and Surveyor. 3 bound vol.
New York City Record. 1 bound vol.
Ontario-Provincial Board of Health. 1 bound vol.
Patton, W. B. 1 pam.
Providence, R. I.-City Engr. 1 pam.
Queensland-Water Supply Dept. 2 maps.
Ry. Equipment and Publication Co. 1 vol.
Rhode Island-State Commr. of Dams and Reservoirs. 1 pam.

Royal Soc. of Canada. 1 bound vol.
Smithsonian Institution. 1 bound vol., 1 vol.
Structural Assoc. of San Francisco. 21 nos.
Transvaal-Mines Dept. 2 vol.
U. S. Bureau of the Census. 1 bound vol.
U. S. Chief of Engrs. 14 specif.
U. S. Forest Service. 4 pam.
U. S. Lake Survey Office. 1 pam., 5 maps.
U. S. National Museum. 3 vol.
U. S. Office of Public Roads. 2 pam.
U. S. Public Health and Marine Hospital Service. 1 vol.
Western Ry Club. 1 bound vol.
Wilgus, W. J. 1 pam.
Wisconsin Univ. 1 vol.

BY PURCHASE.

Technical Year-Book, 1907; ed. by Arthur C. Kelly and Chas. Weekes. London, Percival Marshall & Co., 1907.

Swimming Pools. Their Construction; Mechanical Installation; Water Supply; Heating the Water; Various Types of Installations Adapted to Different Conditions; with Thirty Illustrations and Charts. By Jno. K. Allen. Chicago, Domestic Engineering, 1907.

Trow's General Directory, for the Year ending July 1st, 1908. New York, Trow Directory Company, 1907.

Forest Mensuration. By Henry Solon Graves. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1907.

Drainage Problems of the East: Being a Revised and Enlarged Edition of "Oriental Drainage." By C. C. James. 2 Vol. Vol. 1, Text; Vol. 2, Plans. Bombay, The *Times of India* Office; London, 121 Fleet Street, 1906.

SUMMARY OF ACCESSIONS.

From August 8th to September 10th, 1907.

Donations (including 70 duplicates)	467
By purchase	6
Total	473

MEMBERSHIP.

ADDITIONS.

(August 9th to September 9th, 1907.)

MEMBERS.		Date of Membership.
BEELER, JOHN ALLEN. Vice-Pres. and Gen. Mgr., The Denver City Tramway Co., 617 Majestic Bldg., Denver, Colo..		July 10, 1907
BOYD, JAMES CHURCHILL. With Westinghouse, Church, Kerr & Co., Engrs., 10 Bridge St., New York City	Jun.	Sept. 3, 1895
	Assoc. M.	May 1, 1901
	M.	Sept. 3, 1907
CLARK, ROSCOE NATHANIEL. Asst. City Engr., 800 Main St., Hartford, Conn	Assoc. M.	May 4, 1904
	M.	Mar. 5, 1907
HAM, WILLIAM HALE. Care, Gen. Fireproofing Co., Youngstown, Ohio	Assoc. M.	Nov. 5, 1902
	M.	Sept. 3, 1907
HAYWARD, ROBERT FRANCIS. Gen. Mgr., Mexican Light & Power Co., Ltd., City of Mexico, D. F., Mexico		July 10, 1907
HENDERSON, JOHN THOMAS. Deputy Chf. Engr., Conn. River Bridge and Highway Dist., Hartford, Conn	Assoc. M.	Sept. 3, 1902
	M.	Sept. 3, 1907
HOPSON, ERNEST GEORGE. Asst. Superv. Engr., U. S. Reclamation Service, 307 Tilford Bldg., Portland, Ore		July 10, 1907
MCFETRIDGE, WILLIAM SUTTON. Engr. of Constr., Bangor & Aroostook R. R., La Grange, Me	Jun.	May 3, 1898
	Assoc. M.	Mar. 4, 1903
	M.	Sept. 3, 1907
PRESTON, HENRY WRAY. Engr., Elmira Plant, Empire Bridge Co., Elmira Heights, N. Y.	Assoc. M.	May 3, 1899
	M.	Sept. 3, 1907

ASSOCIATE MEMBERS.		
CARPENTER, CLARENCE EDSON. 33 Bruce Ave., Yonkers, N. Y.		July 10, 1907
DRANE, BRENT SKINNER. Box 89, Carlsbad, N. Mex		July 10, 1907
HARRIS, BORDEN BAKER. Office Engr., Philippine Railway Constr., Manila, Philippine Islands		April 3, 1907
HYDE, JOHN LAWRENCE. Asst. Town Engr., Westfield, Mass.		July 10, 1907
JUBB, SHERMAN AUGUSTUS. 3151 California St., San Francisco, Cal		Mar. 6, 1907
O'CONNOR, CORNELIUS JOSEPH. 1799 Washington Ave., Bronx, New York City	Jun.	Mar. 1, 1904
	Assoc. M.	June 5, 1907
THANHEISER, CHARLES AUGUST. Res. Engr., T. & N. O. R. R., Houston, Tex		July 10, 1907
VLIEGENTHART, JOHANNES CORNELIS. Haiho Conservancy, Tientsin, China		June 5, 1907
WILSON, THAD LOREN. Asst. Engr., Sewer Div., Rapid Transit Comm., 59 Pearl St., New York City		July 10, 1907
WOLCOTT, CHRISTOPHER STANTON. 1353 Pacific St., Brooklyn, N. Y		June 5, 1907

ASSOCIATES.

	Date of Membership.
LUNDBERG, JOHN HERVID. 1258 Bergen St., Brooklyn, N. Y.	April 3, 1907
THOMPSON, EDWARD PERCIVAL. Care, Philippine Products Co., Manila, Philippine Islands	June 5, 1907
VAN NAME, JOSEPH MASON. 1258 Bergen St., Brooklyn, N. Y.	April 3, 1907

JUNIORS.

BARLOW, ALFRED EUGENE, JR. 854 Lafayette Ave., Brooklyn, N. Y.	April 2, 1907
BROADHURST, WILLIAM GEORGE. 538 West 124th St., New York City.	Sept. 3, 1907
BURPEE, GEORGE WILLIAM. P. O. Box 393, Brockton, Mass.	Sept. 3, 1907
MARTIN, WILLIAM FRANKLIN. 515 Merchants Trust Bldg., Los Angeles, Cal.	Mar. 5, 1907
MILLER, HENRY LANARK. Ferro Carril Central de Córdoba, Córdoba, Argentine Republic.	June 4, 1907
SHOEMAKER, HARRY. Box 252, Fort Edward, N. Y.	Sept. 3, 1907

CHANGES OF ADDRESS.

MEMBERS.

BALDWIN, HENRY FURLONG. Chf. Engr., Oregon & Washington R. R. Co., Seattle, Wash.

BEACH, LANSING HOSKINS. Maj., Corps of Engrs., U. S. A., U. S. Engr. Office, Jacksonville, Fla.

BRACKENRIDGE, JOHN CROSBIE. Cons. Engr.; Pres., Rossiter, MacGovern & Co., 90 West St., New York City.

BROWN, EDWARD DU BOIS. Care, Fairbanks, Morse & Co., 12 Dey St., New York City.

CHAMBERS, RALPH HAMILTON. (Chambers & Hone), 15 William St., New York City.

FOSS, FRED EUGENE. Prof. of Civ. Eng. Practice, Carnegie Technical Schools, Pittsburg, Pa.

HARDING, CHESTER. Maj., Corps of Engrs., U. S. A., Gatun, Canal Zone, Panama.

HARMAN, EUGENE LEONARD. U. S. Asst. Engr. with Mississippi River Comm., 1307 Liggett Bldg., St. Louis, Mo.

HARWOOD, GEORGE ALEC. Chf. Engr., Electric Zone Impvts., N. Y. C. & H. R. R. R., 335 Madison Ave., Room 1206, New York City.

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DEATHS.

BIRKS, ARTHUR HENRY. Elected Junior, April 5th, 1904; Associate Member, November 7th, 1906; died August 29th, 1907.

CAMPBELL, ALBERT JOHNSTONE. Elected Associate Member, May 2d, 1894; died June, 1907.

PEARSONS, GALEN W. Elected Member, January 6th, 1875; died August 19th, 1907.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(August 8th to September 10th, 1907.)

NOTE.—*This list is published for the purpose of placing before the members of the Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(1) *Journal*, Assoc. Eng. Soc., 31 Milk St., Boston, Mass., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Blk., Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.

(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
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(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Industrial World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
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(74) *Transactions*, Inst. of Min. and Metal, London, England.
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(79) *Forscherarbeiten*, Vienna, Austria.
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(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Dinglers Polytechnisches Journal*, Berlin, Germany.
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(84) *Le Ciment*, Paris, France.
(85) *Proceedings*, Am. Ry. Eng. and M. of W. Assoc., Chicago, Ill.
(86) *Engineering World*, Chicago, Ill.
(87) *Roadmaster and Foreman*, Chicago, Ill., 10c.

LIST OF ARTICLES.

Bridge.

The Proportioning of Steel Railway Bridge Members.* Henry S. Prichard. (58) July.
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Electrical.

The Necaxa Plant of the Mexican Light and Power Company.* F. S. Pearson and F. O. Blackwell, Members, Am. Soc. C. E. (54) Vol. 58.
The Helion Lamp.* Walter G. Clark and Herschel C. Parker. (6) July.
Selenium Cells.* R. A. L. Snyder. (42) July.
Standardization Rules of the American Institute of Electrical Engineers. (42) July.
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Some New Flywheel Storage Systems.* A. P. Wood. (77) Aug.
The Experimental Determination of the Losses in Motors.* Charles F. Smith. (77) Aug.
A New Leading-In Conductor for Electric Lamps.* C. O. Bastian. (77) Aug.
The Propagation of Electric Waves.* W. M. M. (26) Aug. 2.
The New Power Station of the South Metropolitan Electric Light and Power Co.* (26) Aug. 2.
The Production of High-Frequency Oscillations from the Electric Arc.* L. W. Austin. (Abstract from the *Bulletin* of the U. S. Bureau of Standards.) (73) Aug. 2.
On the Discharge of Condensers Charged by Transformers, and on the Regulation of Resonance Transformers.* A. Blondel. (Abstract from *L'Eclairage Electrique.*) (73) Aug. 2.
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On the Pupin Mode of Working Trunk Telephone Lines.* *Sir* William Preece. (Paper read before the British Assoc. for the Advancement of Science.) (73) Aug. 9.
Wireless Telegraphy—Some of Its Practical and Commercial Aspects. William Maver, Jr. (Paper read before the Assoc. of Ry. Telegraph Supts.) (19) Serial beginning Aug. 10.
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Synchronous Motor Compensation for Lagging Currents.* Clarence P. Fowler. (27) Aug. 10.
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The 50 000-Volt Line of the Taylor's Falls-Minneapolis Power Transmission.* (27) Sept. 7.
Oil-Engine Driven Power Plant of the Pittsfield Electric Company.* (27) Sept. 7.
The Economy of the Tungsten Lamp.* Alfred A. Wohlauer. (27) Sept. 7.
The New York Edison Company's Scrap Heap.* (27) Sept. 7.
Outline of the Characteristics of Constant-Potential Transformers.* Geo. A. Burnham. (27) Sept. 7.
A 40 000-Volt Power Transmission in Lombardia.* (From *Electricity, Power and Gas.*) (24) Sept. 9.
Lifting Magnets and Their Numerous Industrial Applications.* (62) Sept. 9.
La Telegraphie sans Fil.* P. Janet. (32) June.
Installations Hydro-Electriques de l'Energie Electrique du Littoral Méditerranéen.* E. de Marchena. (32) July.
Das Bohren und Nieten von Eisenkonstruktionen mit Elektrischen Pendelbohrmaschinen und Elektrischen Nietmaschinen.* W. Schrader. (82) Serial beginning Aug. 17.

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The "Typhonoid"—A New Type of Motor Boat.* M. J. Peltier. (46) Aug. 24.
Opening of the Large Drydock at League Island.* (46) Aug. 24.
A Floating Dock for Trinidad Wonderfully Equipped.* Harold J. Shepstone. (19) Aug. 31.
The Development of Armored War Vessels.* J. H. Morrison. (19) Serial beginning Aug. 31.
Etude de Quelques Procédés et Méthodes de Sauvetage et de Renflouage des Navires Sous-Marins. M. Dibos. (32) July.

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Deflocculated Graphite. Edward G. Acheson. (42) July.
A French Engineer's Instructions for the Management of Regenerative Furnaces.* (66) Serial beginning July 30.
A New Hydraulic Jack.* (87) Aug.
Wire Ropeways. (From the *World's Carriers.*) (29) Aug. 2.
Why Is It That Some Coals Coke and Others Do Not? F. C. Keighley. (20) Aug. 8.
Modern Practice in Wire-Drawing Machines.* (11) Serial beginning Aug. 9.
Safety Appliances on Speed-Frames in Cotton-Mills.* (11) Aug. 9.
The Present Position of Gas and Petrol Engines.* Dugald Clerk, M. Inst. C. E. (Paper read before the British Assoc. for the Advancement of Science.) (73) Aug. 9; (Abstract.) (26) Aug. 9.
Relative Economy of Steam and Gas Power Where Exhaust Steam is Used for Heating. F. W. Ballard. (Paper read before the Ohio Soc. of Mech., Elec. and Steam Engrs.) (13) Aug. 15; (24) Sept. 2.
Report of Papers read before the Natural Gas Assoc. of America, at Joplin, Mo., May 21-23, 1907.* (83) Aug. 15.
High-Pressure Centrifugal Fans.* A. Rateau. (11) Serial beginning Aug. 16.
Ingot Heating Apparatus.* (12) Aug. 16.
The Stoneywood Paper Works.* (12) Aug. 16.
The Accuracy of Pressure Gauges. (22) Aug. 16.
Mechanical Equipment of the New City Hall at Newark, N. J.* (14) Serial beginning Aug. 17.
The Fuel-Testing Plant of the United States Geological Survey at the Jamestown Exposition.* (27) Aug. 17; (17) Aug. 10.
History and Construction of Steam Gauges.* C. E. Stromeyer. (47) Serial beginning Aug. 17.
The Rolling of Sheet Copper. Copperman. (20) Aug. 22.
Kirkwood Oil Burning Furnaces—An Installation at the Fort Wayne Shops of the Pennsylvania Lines West.* (20) Aug. 22.

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Notes on the Governing of Hydraulic Turbines.* Robert S. Ball. (Paper read before the British Assoc. for the Advancement of Science.) (11) Aug. 23.
Machine for Weighing the Forces on a Cutting Tool.* John F. Brooks. (Paper read before the British Assoc. for the Advancement of Science.) (11) Aug. 23.
The Latest Research on the Specific Heat of Superheated Steam.* Robert H. Smith. (12) Aug. 23.
Some New Steel Foundries.* (22) Aug. 23.
Gasoline 'Buses for New York.* (17) Aug. 24.
The Newman Kinematic Apparatus.* (19) Aug. 24.
Superheated Steam for Steam Turbines.* J. A. Moyer. (From the *Harvard Engineering Journal.*) (47). Aug. 24.
Compressed Air for Steam Hammers. Frank Richards. (62) Aug. 26.
Hot-Coke Conveying Plant at the Paris Gas-Works.* (66) Aug. 27.
The Illuminating Power in Ordinary and Incandescent Burners of Coal Gas, Water Gas, and Mixtures of the Two Gases. Emile Sainte-Claire Deville. (66) Serial beginning Aug. 27.
Some Recent Mechanical Coal Storage Plants.* Wilbur G. Hudson, M. Am. Soc. M. E. (13) Aug. 29.
Two-Stage Operation of a Large Pumping Engine.* A. O. Doane. (13) Aug. 29.
Recent Heavy Cranes in English Shops.* (13) Aug. 29.
Rolling Seamless Tubes.* (20) Aug. 29.
Remarks on Pressure-Gauges.* C. E. Stromeyer. (Abstract) (11) Aug. 30.
Modern Machinery and Its Future Development.* H. J. Brackenbury. (Paper read before the British Assoc. for the Advancement of Science.) (12) Aug. 30; (11) Aug. 30.
Influence of the Lurmann Cinder Notch on the Working of the Blast Furnace.* (22) Aug. 30.
Improved Methods of Dust Prevention in the Grinding Trades.* Samuel R. Bennett. (29) Aug. 30.
The Choice of a Bituminous Coal.* R. H. Kress. (14) Aug. 31.
Electrical Machinery Used in Coke Operations. (14) Aug. 31.
A New Development in Air Compressors.* Frederick A. Halsey. (From the *American Machinist.*) (16) Aug. 31.
Gas Engine Breakdowns.* Michael Longridge. (47) Aug. 31.
A Few Notes on Results of Tests of Worn Ropes. W. Martin Epton. (Paper read before the Transvaal Inst. of Mech. Engrs.) (68) Aug. 31.
The Comparative Cost of Steam and Hydro-Electric Power.* William O. Webber. (9) Sept.
The Growth and Development of the Elevator Industry.* Charles H. Kloman. (10) Sept.
The Flash Steam Generator.* H. W. Bolsover. (10) Sept.
Boiler-Room Design and Equipment.* Wm. H. Bryan, M. Am. Soc. M. E. (10) Sept.
Autogenous Welding.* F. C. Cutler. (10) Sept.
Physical Properties of Saturated Steam.* Fred R. Low. (64) Sept.
Indicator Diagrams from a Canadian Crude-Oil Engine.* H. Addison Johnston. (64) Sept.
Mains and Fittings for Gas-Power Plants. L. L. Brewer. (64) Sept.
Pressures and Work in a Gas Engine.* Cecil P. Poole. (64) Sept.
Test of Tube-Connected Cylinders.* S. F. Jeter. (64) Sept.
The Manufacture of Peat-Fuel in Michigan—Description of the "Wet Process."* Francis J. Bulask. (64) Sept.
Improvements in the Vertical-Plunger Sinking Pump.* A. H. Hale. (64) Sept.
Best Method of Supplying Oil to Turbines.* Thomas Franklin. (64) Sept.
Saving Exhaust Steam from an Intermittently Running Engine.* (64) Sept.
Rigid and Other Joints.* H. W. (From the *Gas World.*) (24) Sept. 2.
Acetylene Lighting.* Nelson Goodyear. (Paper read before the Illuminating Eng. Soc.) (83) Sept. 2.
Everit Tar-Naphthalene Extractor.* J. D. Smith. (Paper read before the North British Assoc. of Gas Mgrs.) (83) Sept. 2.
Use of By-Product Coke Oven Gas. C. E. Rhodes. (Abstract from paper read before the Inst. of Gas Engrs.) (83) Sept. 2.
Hot Water Boiler Washing. (Abstract of Committee Report to Traveling Engrs.' Assoc.) (18) Sept. 7; (40) Sept. 6.
Manufacture of Boiler Tubes. F. N. Speller. (Paper read before the Richmond Ry. Club.) (18) Sept. 7.
Engine Driven Centrifugal Pumps: Their Capacities, Limitations and Duties.* (18) Sept. 7.
Oil-Engine Driven Power Plant of the Pittsfield Electric Company.* (27) Sept. 7.
Formule Relative a une Condition de Stabilité des Automobiles et Spécialement des Autobus: Oscillations Diverses.* Georges Marie. (32) June.
L'Art de Couper les Métaux.* C. Condron. (37) Serial beginning July 31.
Théorie de l'Autoloc.* L. Lecornu. (37) July 31.
L'Exactitude de la Formule de Rankine et l'Influence des Encastrements dans les Longues Pièces Comprimées.* Gustave L. Gérard. (30) Aug.

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Compresseur d'Air Compound à Double Compression.* Jean Grégoire. (34) Aug.
Extinction et Manutention du Coke dans les Usines à Gaz; Extinction et Transport par un Courant d'Eau.* A. Thibeault. (33) Aug. 3.
Le Coupage des Métaux par l'Oxygène.* Leon Guillet. (33) Aug. 10.
Le Problème de l'Aviation et la Résistance de l'Air.* E. Maleire. (33) Serial beginning Aug. 10.
La Manutention Mécanique dans les Journaux et dans les Papeteries.* Ch. Dantin. (33) Aug. 17.
Die Bearbeitung der Ringschmierlager.* C. Volk. (48) Aug. 10.
Die Nebenspannung in Rasch Umlaufenden Scheibenrädern.* A. Stodola. (48) Aug. 10.
Ueber Wassergas.* H. Dicke. (50) Serial beginning Aug. 14.
Kreiselgebläse für Hohen Druck.* A. Rateau. (48) Aug. 17.
Konstruktionsgrundlagen für den Bau von Kraftwagen.* Ernest Valentin. (48) Aug. 24.

Metallurgical.

Copper Steels.* Pierre Breuil. (71) Vol. 74.
Cast Iron as Cast and Heat Treated.* W. H. Hatfield. (71) Vol. 74.
The Non-Metallic Impurities in Steel.* E. F. Law. (71) Vol. 74.
Boron Steels.* Leon Guillet. (71) Vol. 74.
Address on the Effect of Air and Moisture on Blast-Furnaces, Delivered at Bradford (England), June 11, 1800. Joseph Dawson. (71) Vol. 74.
Eighth Report to the Alloys Research Committee: On the Properties of Alloys of Aluminium and Copper.* H. C. H. Carpenter and C. A. Edwards. (75) Mar., 1907.
The Treatment of Zinc Ores in Colorado.* F. W. Traphagen. (45) Aug.
The Washoe Smelter.* (45) (Abstract.) Aug.
The Betts Process at Trail, B. C.: Electrolytic Refining of Lead Bullion. Treatment of Gold and Silver Slimes, Copper Sulphate Recovery.* A. G. Wolf. (Paper read before the Western Assoc. of Technical Chemists and Metallurgists.) (45) Aug.
Malleable Castings.* E. L. Rhead. (47) Serial beginning Aug. 3.
Experiments with Cylinder Irons. R. Buchanan. (Abstract of paper read before the Cleveland (England) Inst. of Engrs.) (22) Aug. 9.
Electric Tempering Furnaces. (Tr. from *L'Elettricita.*) (68) Aug. 17.
Magnetic Concentration of Iron Ores by the Gröndal Process. (Abstract of paper read before the Canadian Min. Inst.) (22) Aug. 23.
The Nordberg Compound Steam Stamp.* (16) Aug. 24.
Manganese in Cast Iron. Herbert E. Field. (Paper read before the Amer. Foundrymen's Assoc.) (47) Aug. 24.
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Goldschmidt Thermit Steel Valuable for Welding Purposes.* (62) Sept. 2.
Influence of Iron in Copper Electrolysis. E. L. Larison. (16) Sept. 7.
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Chariot à Commande Hydro-Electrique pour Porche de Coulée de 20 Tonnes.* (33) Aug. 17.
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Ueber den Gegenwärtigen Stand der Schlagbiegeprobe mit Eingekerbten Stäben. (50) Serial beginning July 31.

Military.

The Single-Type Projectile Problem. (11) Aug. 16.
The Dynamics of Long Recoil.* A. G. Greenhill. (12) Aug. 23.

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Polmaise Collieries.* James Salmond. (59) Vol. 29, Pt. 5.
Bituminous Coal Washing. G. R. Delamater. (45) Serial beginning Aug.
Notes on Hydraulic Mining, With Special Reference to the Cariboo District, British Columbia, and Yukon Territory.* (45) Aug.
Recent Testing of Coal Used by the Federal Government in its Public Buildings at Washington, D. C.* J. A. Holmes and D. T. Randall. (45) Aug.
The Daly-Judge Mine and Mill, Park City, Utah.* Paul A. Gow and others. (Abstract.) (45) Serial beginning Aug.
Colliery Warnings. (57) Aug. 9.
The Black Sand Problem.* F. Powell. (16) Aug. 10.
Mining Methods on the Gogebic Iron Range.* Reginald Meeks. (16) Aug. 10.
Ground Breaking in the Joplin (Mo.) District.* Doss Brittain. (16) Aug. 10.
The Ultimate Crushing Strength of Coal.* Joseph Daniels and L. D. Moore. (16) Aug. 10.
The Nomenclature of Modern Placer Mining.* J. P. Hutchins. (16) Aug. 10.

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A Mine Dam to Recover Flooded Workings.* John H. Haertter. (16) Aug. 10.
Fighting a Colliery Fire. W. H. Pickering and R. R. Simpson. (Abstract of paper read before the Min. and Geological Inst. of India.) (22) Aug. 16.
Electrical Winding Plant at Mattias Stinnes Colliery. D. Selby-Bigge. (Abstract of paper read before the South Wales Inst. of Engrs.) (22) Aug. 23.
The Essential Data of Placer Investigation.* J. P. Hutchins. (16) Serial beginning Aug. 24.
A Cripple Creek Ore-Handling Plant.* S. A. Worcester. (16) Aug. 24.
Mining and Smelting at Granby, Missouri.* Edwin T. Perkins. (16) Aug. 31.
Setting Timber in Anthracite Coal Mines.* John H. Haertter. (16) Aug. 31.
The Effect of Barometric Variation on the Outflow of Gas in Mines. W. H. Booth. (16) Aug. 31.
Care of Mine Mules.* I. C. Newhard. (Abstract.) (45) Sept.
Mining Conditions in South Africa.* J. B. Pitchford. (Lecture delivered before the Mining Students of the Univ. of California.) (45) Sept.
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Concrete Overcasts in Coal Mines.* John H. Haertter. (16) Sept. 7.
Mining the Porphyry Ore of Bingham (Utah).* Walter Renton Ingalls. (16) Sept. 7.
Possibilities of Electricity in Metal Mining.* G. M. Dyott. (27) Sept. 7.

Miscellaneous.

The Engineer as a Professional Man: (Presidential) Address at the Annual Convention (Am. Soc. Civ. Engrs.), City of Mexico, July 8th, 1907. George H. Benzenberg, President, Am. Soc. C. E. (54) Vol. 58.
Engineers' Contracts and Specifications from a Contractor's Point of View. James W. Rollins, Jr. (1) July.
Illumination Photometers and Their Use.* Preston S. Millar. (Paper read before the Illuminating Eng. Soc.) (24) Aug. 19.
The Library System of Stone & Webster. (14) Aug. 24.

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The Application of Tar to Macadamized Roads. Thomas Aitken. (Abstract of paper read before the Assoc. of Municipal and County Engrs.) (13) Aug. 22.
The Asphalt Pavement on the Thames Embankment.* (14) Aug. 24.
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Tarring Road Surfaces. J. W. Howard. (Abstract of paper read before the Amer. Road Makers' Assoc.) (83) Sept. 2.

Railroad.

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Some Facts and Problems Bearing on Electric Trunk-Line Operation.* Frank J. Sprague. (42) July.
Single-Phase Versus Three-Phase Generation for Single-Phase Railways.* A. H. Armstrong. (42) July.
The Choice of Frequency for Single-Phase Alternating-Current Railway Motors.* A. H. Armstrong. (42) July.
Twenty-five Versus 15 Cycles for Heavy Railways. N. W. Storer. (42) July.
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Siemens Bros. "All-Electric" Signalling and Interlocking Plant.* (21) Serial beginning Aug.
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Rail Motor-Cars. (Abstract of report made to the Amer. Master Mechanics' Assoc.) (47) Aug. 10.
Standard Turntable Pit: Seaboard Air Line Ry.* Philip Aylett, Assoc. M. Am. Soc. C. E. (13) Aug. 15.
Center-Bound Track as a Cause of Spreading Rails. (Abstract of paper in *The Technograph*, Vol. XXI, 1906-07.) (13) Aug. 15.
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The Land and Water Terminal of the Seaboard Air Line Railway at Savannah, Ga.* W. D. Faucette. (Abstract of paper read before the Associated Engr's. and Constructor's Soc. of Tidewater, Va.) (13) Aug. 22.
Steel Rails of Better Quality. Robert Job. (20) Aug. 22.
Note on the Economic Renewal and Maintenance of Railway Tracks for High-Speed Traffic.* L. Schlüssel. (Abstract fr. *Bulletin*, Inter. Ry. Cong. Assoc., Apr., 1907.) (12) Aug. 23.
A Note on Compound Locomotives.* Maurice Demoulin. (12) Serial beginning Aug. 23.
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Some Cost Figures on Forest Planting for Railroad Purposes. E. A. Sterling. (13) Aug. 29.
Construction of Second Track Accompanied by Reduction of Gradient. H. H. Knowlton. (Abstract of paper in the *Purdue Engineering Review.*) (13) Aug. 29.
Causes of Leaks in Locomotive Boiler Tubes.* M. E. Wells. (Abstract of paper read before the Amer. Railway Master Mechanics' Assoc.) (13) Aug. 29.
Solid Steel Wheels for Passenger Cars. George L. Fowler. (Abstract of discussion before the Master Car Builders' Assoc.) (20) Aug. 29.
Long Island City Power-Station of the Pennsylvania Railroad Company.* (11) Serial beginning Aug. 30.
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Note sur le Défaut de Nivellement Parfait de la Surface de Roulement de Certains Rails en Acier Dur et les Inconvénients qui en Résultent.* E. Perroud. (38) Aug.
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Die Offenen Strecken der Neuen Alpenbahnen.* J. Zuffer. (53) Aug. 2.
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The Origin and Production of Corrugation of Tramway Rails. W. Worby Beaumont, M. Inst. C. E. (Abstract of paper read before the British Assoc. for the Advancement of Science.) (26) Aug. 9.
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Rainfall and Run-Off in Storm-Water Sewers.* Charles Emerson Gregory, Assoc. M. Am. Soc. C. E. (54) Vol. 58.
Typhoid Mortality in South Bethlehem, Pa. Mansfield Merriman and Winter L. Wilson, Members, Am. Soc. C. E. (54) Vol. 58.
Administration of Pennsylvania Laws Respecting Stream Pollution. F. Herbert Snow. (58) July.
Present Condition of Municipal Sewers of Pittsburg. I. Charles Palmer. (58) July.
Heating and Ventilating a Group of Public Schools.* S. R. Lewis. (Paper read before the Amer. Soc. of Heating and Ventilating Engrs.) (76) Aug.

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Sewage Experiments at Matunga, Bombay.* Gilbert J. Fowler. (13) Aug. 8.
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Relative Economy of Steam and Gas Power Where Exhaust Steam is Used for Heating. F. W. Ballard. (Paper read before the Ohio Soc. of Mech., Elec. and Steam Engrs.) (13) Aug. 15.
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The Revised Sanitary Code of the Town of Montclair, N. J. (13) Aug. 22.
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The Use and Abuse of Sewage Purification Plants. A. Elliott Kimberly. (Abstract from paper read before the Ohio Eng. Soc.) (13) Aug. 29; (14) Aug. 31.
Constructing a Sewer Under the Brooklyn Subway.* (14) Aug. 31.

Structural.

The Fatigue of Concrete.* J. L. Van Ornum, M. Am. Soc. C. E. (54) Vol. 58.
The Proposed Testing Laboratory of the Department of Civil Engineering (Columbia University).* William H. Burr. (6) July.
Method of Constructing the Foundations for the Trust Company of America Building, New York City.* Maurice Deutsch. (6) July.
A Briquette Testing Machine of the Pendulum Type.* H. F. Moore. (67) Aug.
The Open-Tank Method for Treatment of Timber.* (Abstract from Circular No. 101, Forest Service, U. S. Dept. of Agri.) (87) Aug.
Priming Coats for Metal Surfaces: Linseed Oil *vs.* Paint. F. P. Cheesman. (Abstract of paper read before the Amer. Soc. for Testing Materials.) (13) Aug. 8.
Cost of Shop Drawings for Structural Iron and Steel. Ralph H. Gage. (Abstract of paper from *The Technograph*, No. 21, 1906-07.) (13) Aug. 8.
Standard Specifications for Structural Timber: Amer. Soc. for Testing Materials. (15) Aug. 9.
Tests of Concrete Columns.* Arthur N. Talbot. (Paper read before the Amer. Soc. for Testing Materials.) (14) Aug. 10.
The New Warehouse of the Newark Warehouse Company.* (14) Aug. 10.
Investigation of the Thermal Conductivity of Concrete and Embedded Steel and the Effect of Heat Upon Their Strength and Elastic Properties.* Ira H. Woolson. (Paper read before the Amer. Soc. for Testing Materials.) (13) Aug. 15.
The Chateau des Beaux-Arts on Huntington Bay.* (14) Aug. 17.
Tension Tests of Steel Angles with Various Types of End-Connection.* Frank P. McKibben. (Paper read before the Amer. Soc. for Testing Materials.) (13) Aug. 22.
Ferro-Concrete and Examples of Construction. J. S. E. De Vesian, M. Inst. C. E. (Paper read before the British Assoc. for the Advancement of Science.) (22) Aug. 23.
Retaining the Sides of a Large Excavation.* (14) Aug. 24.
The Construction of the New York Central Office Building, New York.* (14) Aug. 24.
Treatment of Concrete Surfaces. Linn White. (18) Aug. 24.
A Long-Span Truss Roof: Armory for Squadron C, New York National Guard, New York City.* (13) Aug. 29.
Symmetrical Masonry Arches, Coefficients for Reactions and Moments at the Supports. Malverd A. Howe. (15) Aug. 30.
The Electrolytic Theory of the Corrosion of Iron. Allerton S. Cushman. (19) Serial beginning Aug. 31; (20) Aug. 8.
The Design and Construction of Industrial Buildings.* D. C. Newman Collins. (9) Sept.
Steel Sheet Piling. (62) Sept. 2.
Fall of a 150-Ft. Reinforced Tile-and-Concrete Chimney at La Crosse, Wis.* (13) Sept. 5.
Effect of Steam Curing on the Crushing Strength of Concrete.* (13) Sept. 5.
A Combined Underpinning and Sheeting Job (Murray Street Building, New York City).* (14) Sept. 7.
The New Manufacturing Plant of the George N. Pierce Co., Buffalo, N. Y.* (14) Sept. 7.
The Erection of the 612-Foot Singer Building.* (46) Sept. 7.
Moving the Montauk Theatre.* (46) Sept. 7.
Le Glissement des Armatures. (84) July.
Etude d'un Phénomène de Dissociation de Mortier de Ciment par Infiltration d'Eau. (84) Serial beginning July.
Le Calcul des Flèches des Poutres par l'Intégration Graphique.* E. Aragon. (33) Serial beginning Aug. 17.
Fundierung und Grundwasser-Abdichtung für den Erweiterungsbau der Bank für Handel und Industrie zu Berlin.* Th. Gesztessy. (78) Aug.

*Illustrated.

Structural—(Continued).

Vergleichende Kostenberechnung der Eisenarmierung aus Biegungsfesten Profileisen und aus Stabeisen für Verbundbalken von Grösserer Stützweite.* Weidmann. (78) Aug.

Angebliche Haftfestigkeitsunterschiede bei Kalksandsteinen und Ziegeln. Prof. Germer. (80) Aug. 1.

Die Ergebnisse der Probebelastung Durchgehender mit den Unterstützenden Trägern Zusammenhängender Platten.* Koenen. (Paper read before the Deutscher Beton-Verein E. V.) (80) Aug. 1.

Ueber die an der k. k. Forstlichen Versuchsanstalt Mariabrunn Gewonnenen Resultate der Holzfestigkeitsprüfungen.* Gabriel Janka. (53) Serial beginning Aug. 9.

Versuch über die Schubwirkung bei Eisenbeton. Emil Mörsch. (Paper read before the Deutscher Beton-Verein E. V.) (80) Aug. 10.

Topographical.

History of Map Making and Topography.* C. W. Larned. (19) Serial beginning Aug. 24.

Water Supply.

Recent Practice in Hydraulic-Fill Dam Construction.* James D. Schuyler, M. Am. Soc. C. E. (54) Vol. 58.

The Design of the New Croton Dam.* Edward Wegmann, M. Am. Soc. C. E. (54) Vol. 58.

Additional Information on the Durability of Wooden Stave Pipe.* Arthur L. Adams, M. Am. Soc. C. E. (54) Vol. 58.

Hydraulic Formulæ: Development and Discussion.* Adolph Black. (6) July.

Pumping Machinery for Dalny Water-Works.* (12) Aug. 2.

New Water Purification Plant at Exeter, N. H.* Robert Spurr Weston. (13) Aug. 8.

Experiments with a Jewell Filter at the Posen Water Works. E. A. Gieseler. (14) Aug. 10.

A Reinforced Concrete Water Tower at Anaheim (Cal.).* (14) Aug. 14.

Comparative Costs of Gasoline, Gas, Steam and Electricity for Small Powers.* William O. Webber. (13) Aug. 15.

Cleaning an 8-In. Cast-Iron Water Main in Pittsburg, Pa.* J. D. Underwood. (13) Aug. 15.

Electrically-Operated Water-Works of Tacoma, Wash.* H. Cole Estep. (27) Aug. 17.

A New Egyptian Irrigation Canal.* J. B. Van Brussel. (46) Aug. 17.

Some Notes on Oriental Water-Works. George A. Johnson. (Paper read before the Amer. Water-Works Assoc.) (14) Aug. 24.

A Buttressed Concrete Dam.* (14) Aug. 24.

The Wood-Stave Pipe Line of the Madison River Power Company.* W. E. Belcher. (16) Aug. 24.

Movable Crest Dams at the Water Power Development of the Chicago Drainage Canal.* (14) Aug. 24.

Reconstructing a Masonry Dam for Increased Depth of Storage.* (13) Aug. 29.

Irrigation in Western Canada. (11) Aug. 30.

Speed Regulation for High-Head Water-Wheels. (14) Aug. 31.

The Water Purification and Softening Works at New Orleans, La.* (14) Aug. 31.

An Infiltration Water-Works Intake Under the Ohio River.* (14) Aug. 31.

Direct and Indirect Methods of Electrical Purification of Water.* Henry Leffmann. (3) Sept.

The Comparative Cost of Steam and Hydro-Electric Power.* William O. Webber. (9) Sept.

The Water Filtration Plant at Harrisburg, Pa.* (60) Sept.

Forests and Run-Off. (14) Sept. 7.

The Hydro-Electric Development of the Great Northern Power Co.* (14) Serial beginning Sept. 7.

A 7-Ft. Steel Pipe Line at St. Louis.* (14) Sept. 7.

The Detection of Pollution in Underground Waters. John C. Thresh. (Abstract of paper read before the Assoc. of Water Engrs.) (14) Sept. 7.

Ueber den Freien Ausfluss von Flüssigkeiten an Mündungen bei Unvollkommener Kontraktion. A. Jarolimek. (53) Aug. 9.

Waterways.

The Naval Floating Dock—Its Advantages, Design and Construction.* Leonard M. Cox, M. Am. Soc. C. E. (54) Vol. 58.

Lighthouse Construction in the Philippines.* Spencer Cosby, M. Am. Soc. C. E. (54) Vol. 58.

The Atchafalaya River: Some of Its Peculiar Physical Characteristics.* J. A. Ockerson, M. Am. Soc. C. E. (54) Vol. 58.

Twenty Years' Run-Off, at Holyoke, Mass., of the Connecticut River. Clemens Herschel, M. Am. Soc. C. E. (54) Vol. 58.

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*Illustrated.

Waterways—(Continued).

Floods and Means of Their Prevention in Our Western Rivers. T. P. Roberts. (58) July.

Failure of Masonry Arch Carrying Erie Canal over Onondaga Creek, Syracuse, N. Y.* (13) Aug. 8.

Destruction of Debris Barrier No. 1, Yuba River, California.* E. C. Murphy, Assoc. M. Am. Soc. C. E. (13) Aug. 8.

The Locust Point Pier Collapse in Baltimore.* (13) Aug. 8.

The Ice Problem in Engineering Work in Canada.* Howard T. Barnes. (Paper read before the British Assoc. for the Advancement of Science.) (11) Aug. 9.

Sea Defence Works at Hornsea (England).* (12) Aug. 9.

New Entrance Channel at Saint Nazaire.* (12) Aug. 9.

Submarine Signalling.* (12) Aug. 16.

The Contractor's Plant and Methods on the Harbor Work at Gary, Ind.* (14) Aug. 17.

Stone Breakwater Construction at Huron, Ohio.* Wilson T. Howe. (13) Aug. 22.

Water Level Gages.* Robert E. Horton, Assoc. M. Am. Soc. C. E. (13) Aug. 22.

The Land and Water Terminal of the Seaboard Air Line Railway at Savannah, Ga.* W. D. Faucette. (Abstract of paper read before the Associated Engr's. and Constructor's Soc. of Tidewater, Va.) (13) Aug. 22.

Southern Appalachian Streams.* Charles E. Waddell. (3) Sept.

The Launch of the Caissons Recently Built at the Norfolk Navy Yard.* (46) Sept. 7.

Les Observations de Courants à Zeebrugge.* Urbain et Allaeys. (30) Aug.

Ueber Konstruktion und Berechnung von Kaimauern mit Hinterlast.* H. Zuckschwerdt. (8) Vol. 4, 1907.

Die Erweiterung des Kaiser Wilhelm-Kanales.* Scholer. (Paper read before the Verband Deutscher Architekten- und Ingenieur-Vereine in Kiel.) (51) Aug. 24.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

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WATER PURIFICATION AT ST. LOUIS, MO.

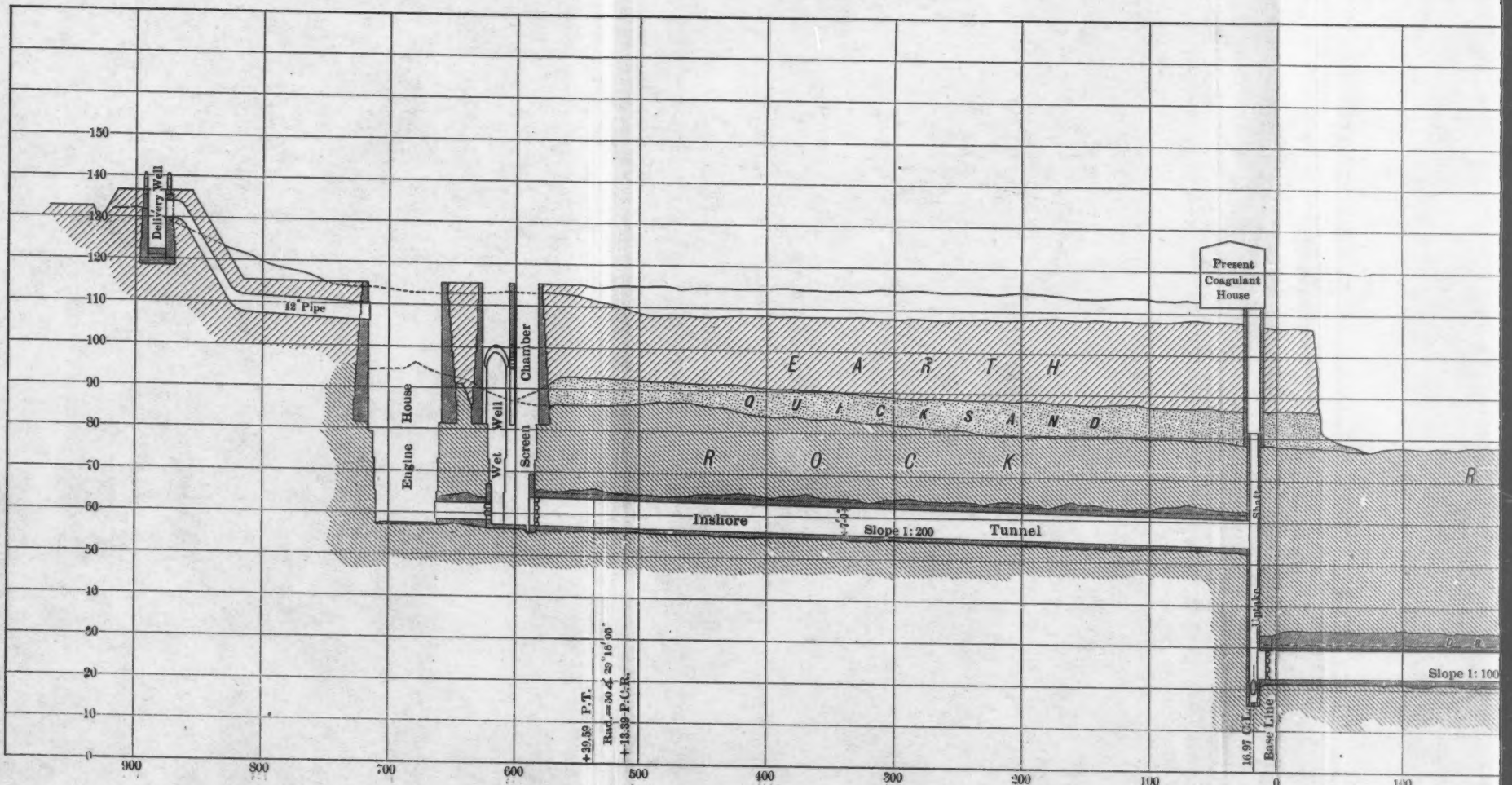
By Edward E. Wall, M. Am. Soc. C. E.

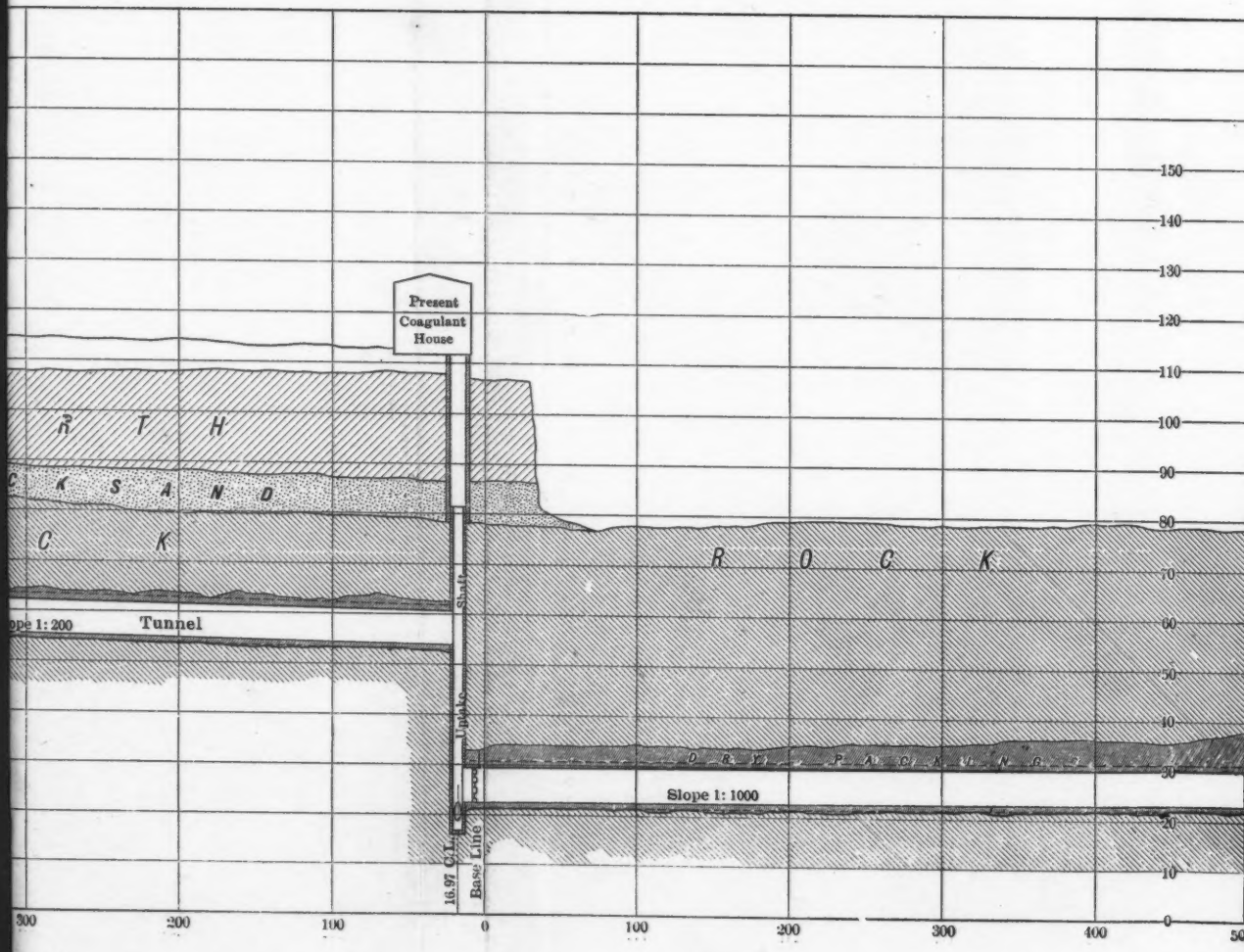
To be Presented November 6th, 1907.

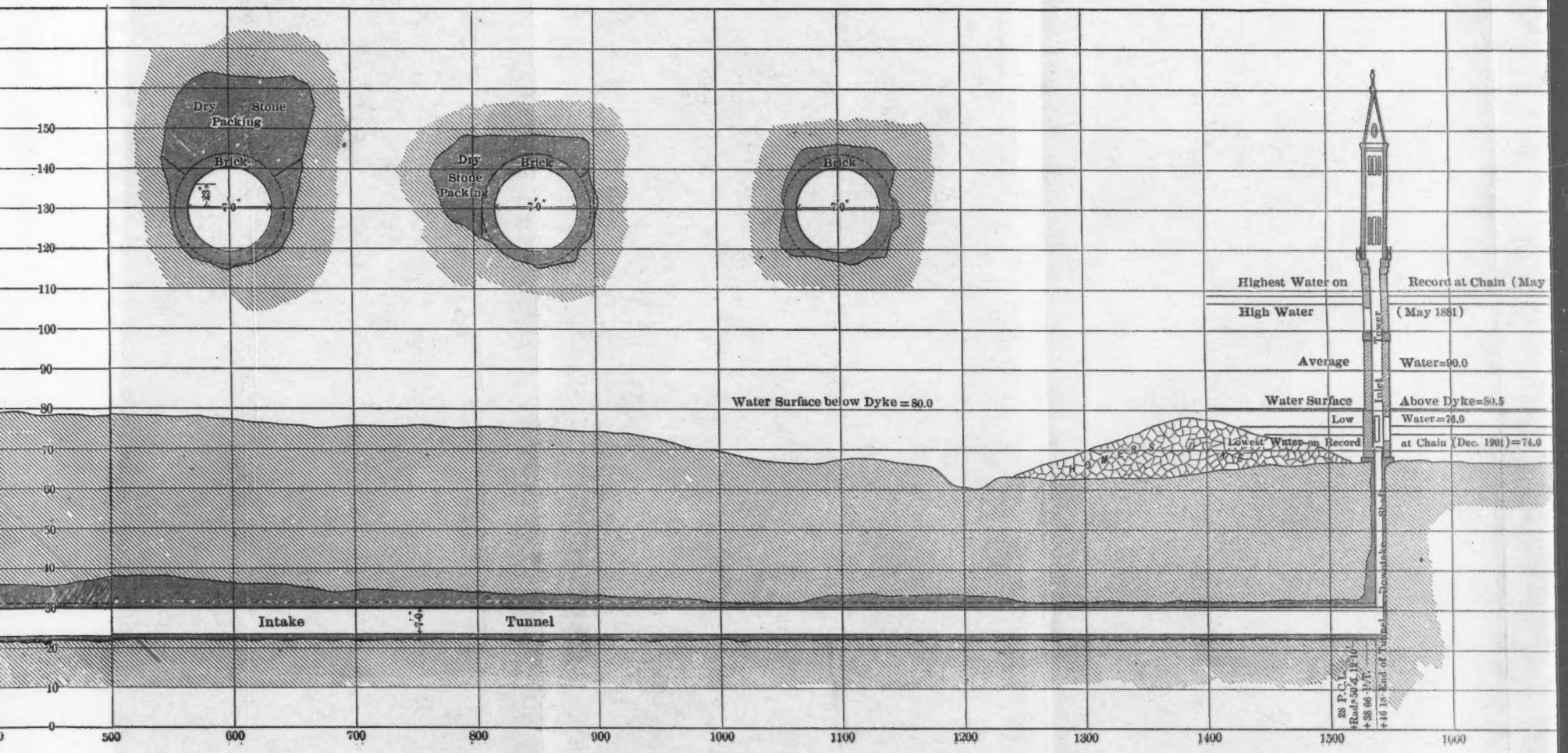
Previous to 1904, St. Louis was famous for the muddy water supplied to its inhabitants and visitors. The inhabitants, never having known anything else, had ceased to pay attention to the appearance of the water, accepting it as a matter of course, just as they endured the wind and the weather, and were inclined to be amused at "the stranger within their gates," who protested against drinking and bathing in the coffee-colored fluid. Visitors to St. Louis in the summer and autumn of 1904, who had previously been in the city, were amazed to find clear, sparkling water in general use even for sprinkling and street washing. The history of events leading up to this sudden and remarkable change in the water supply of St. Louis, and a description of the purification process as finally developed and used, cannot fail to be of interest to engineers, especially to those engaged on waterworks and in the investigation of water supplies.

In May, 1903, Mr. Ben C. Adkins was made Water Commissioner of St. Louis, and the writer was appointed by him as Principal As-

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.


Delivery Well
42" Pipe
Engine House
Wet Well
Screen Chamber
Present Coagulant House
E A R T H
Q U I C K S A N D
R O C K
Inshore
Slope 1: 200
Tunnel
Shaft
Uptake
Slope 1: 100
P.T.
+39.89
Rad. = 30 ft. 29' 16"
+13.39 P.C.R.
C.L.
16.97
Base Line
900
800
700
600
500
400
300
200
100
0
100
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0


Present
Coagulant
House
R T H
K S A N D
C K
R O C K
Tunnel
Shaft
Slope 1: 200
Slope 1: 1000
Base Line
16.97 O.D.
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
300
200
100
0
100
200
300
400


Dry Stone Packing
Brick
7'0"
Dry Stone Packing
Brick
7'0"
Brick
7'0"
Water Surface below Dyke = 80.0
Highest Water on Record at Chain (May
High Water (May 1881)
Average Water=90.0
Water Surface Above Dyke=80.5
Low Water=76.0
Lowest Water on Record at Chain (Dec. 1901)=74.0
Tower
Inlet
Shaft
Dowdake
End of Tunnel
Intake
7'0"
Tunnel
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600

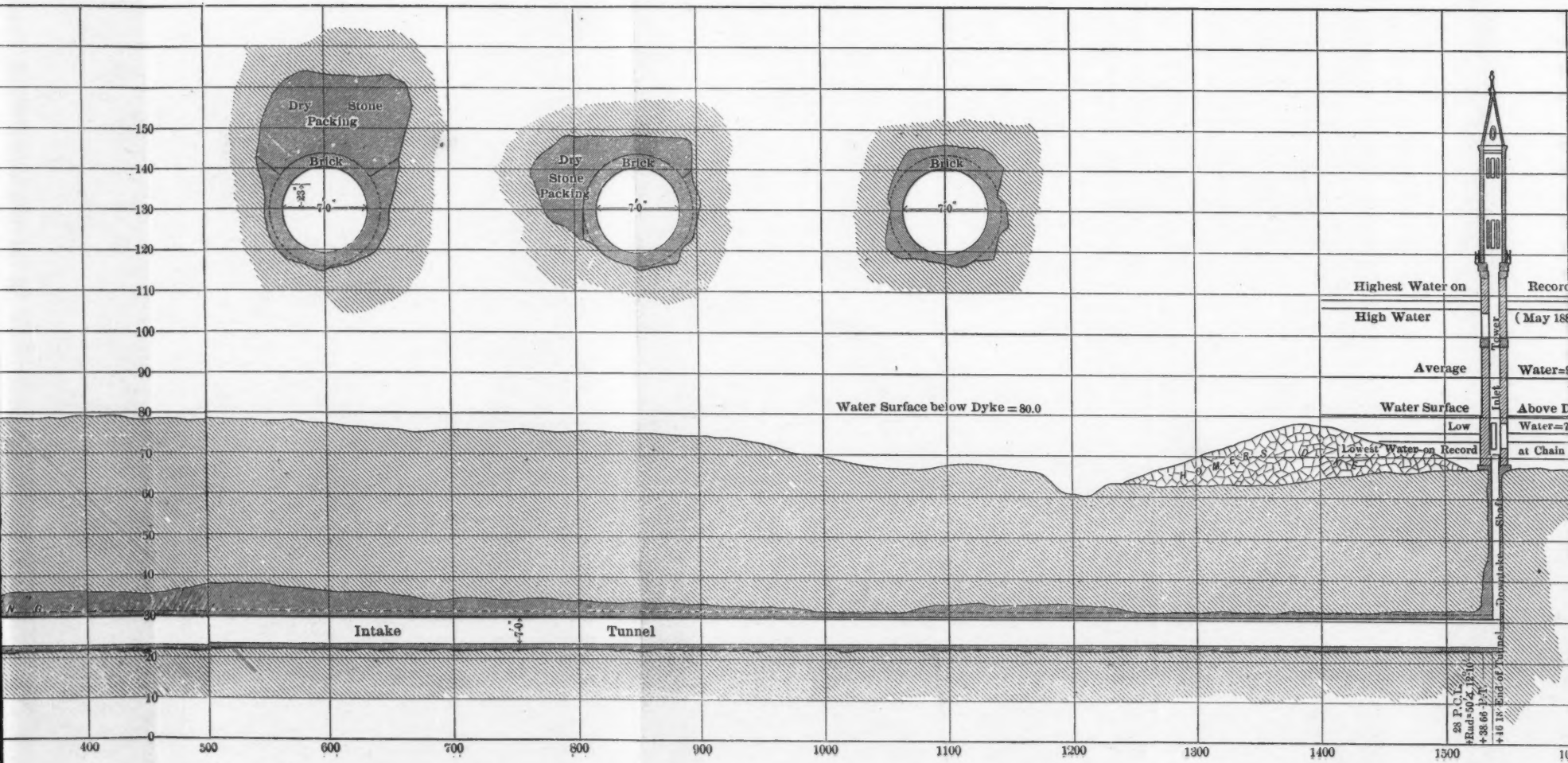
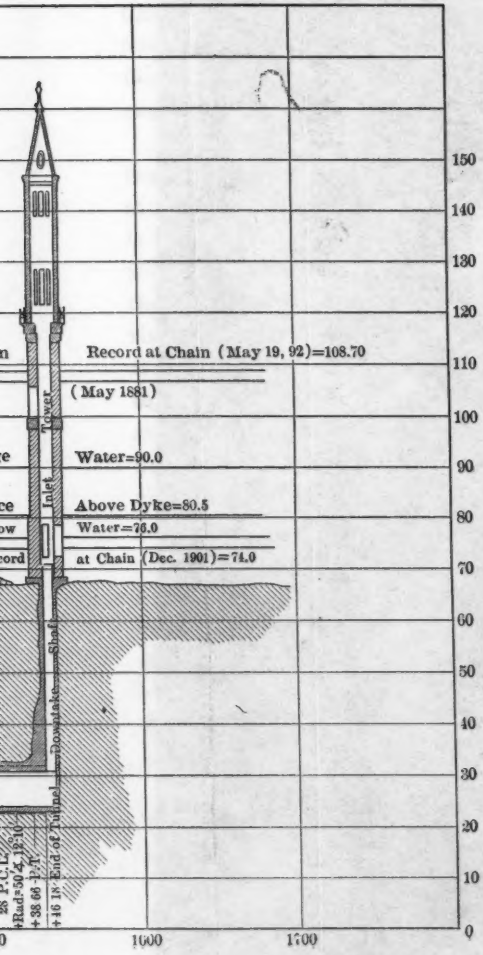

Dry Stone Packing
Brick
7'0"
Dry Stone Packing
Brick
7'0"
Brick
7'0"
Water Surface below Dyke = 80.0
Highest Water on
High Water
Average
Water Surface
Low
Lowest Water on Record
Tower
Inlet
Shaft
Downlake
Intake
7'0"
Tunnel
28 P.C.I.
+Rad=50'
+38.66
+10 18" End of Tunnel
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500

PLATE LXXV.
PAPERS, AM. SOC. C. E.
SEPTEMBER, 1907.
WALL ON
WATER PURIFICATION AT ST. LOUIS, MO.



LOW SERVICE EXTENSION
PROFILE OF TUNNEL LINE
AT
CHAIN OF ROCKS

sistant Engineer, the position of Assistant Water Commissioner being created later.

The most important question confronting the Department at that time was to devise some method of improving the appearance of the water, which should be of such design that it could be put into operation previous to the opening of the World's Fair, that is, in less than one year.

A brief description of the water-works will be necessary in order that the conditions existing at that time, and the changes that were afterward made, may be understood. The water supply of St. Louis is taken from the Mississippi River at the Chain of Rocks, about ten miles above the Eads Bridge, which spans the river approximately at the center of the city. The intake tower stands near the middle of the river, resting on bed-rock and built over a 7-ft. shaft leading down to a tunnel some 50 ft. below the river bed. This tunnel is also 7 ft. in diameter and terminates at the river bank at the base of the uptake shaft, which connects the river and the shore tunnels. The shore tunnel, also 7 ft. in diameter, is about 30 ft. nearer the surface than the river tunnel, and ends at the wet well from which the low-service pumps take their supply. (Plate LXXV.)

The low-service pumps deliver the water to a well at the head of a 9 by 11-ft. horseshoe-shaped conduit, which runs along the ends of a series of six settling basins, each 400 by 670 ft., with connections and gates for filling each basin separately. At the opposite ends of these basins is another 9 by 11-ft. conduit with connections to each basin for drawing off the water. This drawing conduit carries the water to the high-service stations several miles below. (Fig. 1.)

Previous to 1903, the operation of the settling basins consisted in a separate filling and drawing of each basin, allowing as long a time as possible for settlement before drawing off the water for delivery to the high-service pumps. This time usually varied from 12 to 24 hours, during which the heaviest and coarsest portion of the suspended matter fell to the bottom, but so much finely divided matter remained in suspension that the casual observer could scarcely notice any difference between the river water and that delivered to the consumer.

The river water carries in suspension amounts varying from 20 to 6 000 parts per million, according to the stage of the river, the solids in solution varying from 140 to 400 parts per million, the bacteria ranging from 2 000 to 250 000 per cu. cm.

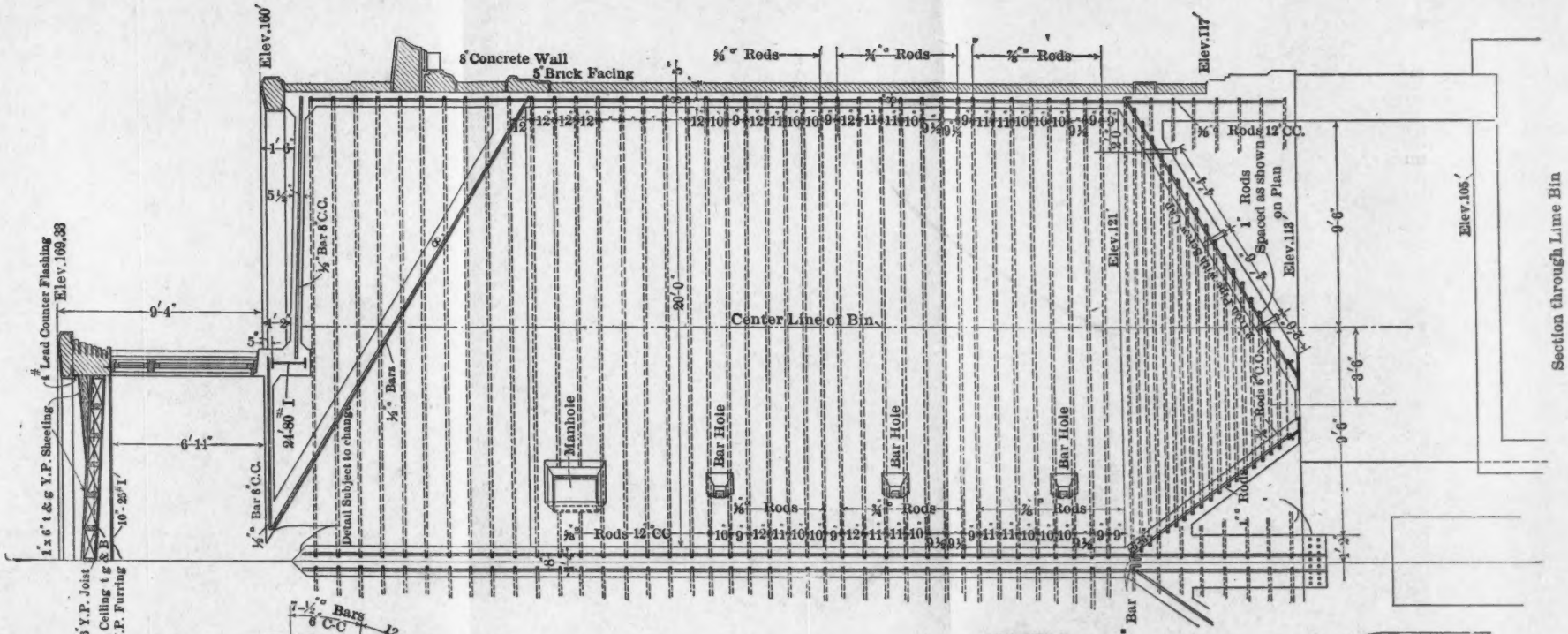
The method of simple sedimentation reduced the suspended solids from 10 to 80%, the number of bacteria being reduced probably in the same ratio, but was eminently unsatisfactory because of the low percentage of improvement and the scarcely perceptible change in the appearance of the water.

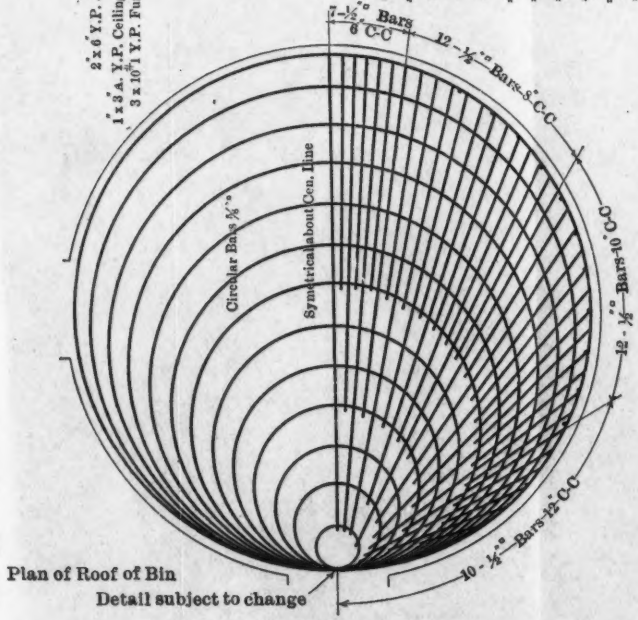
The problem of devising a better system of clarifying and purifying the water supply of St. Louis had been studied and discussed by the best hydraulic engineers in the country. Filtration plants at home and abroad had been examined and studied, and various projects had been offered as solutions of the problem. For 40 years the question had occupied a prominent place in all propositions connected with the improvement and extension of the water-works. All proposed schemes for clarifying and purifying the water supply, which were worthy of serious consideration, involved the expenditure of millions, and necessitated the building of works which would take years to complete.

Many years ago it was proposed to abandon the Mississippi River as a source of supply and to go some 90 miles away to the Meramec Springs. Another proposition was to move the intake to the Missouri River above St. Charles, Mo. These schemes contemplated furnishing the water to the city by gravity flow, the Meramec project involving the construction of an immense impounding reservoir with miles of masonry conduit, steel pipe and tunnels, while the Missouri River plan required the building of a new low-service pumping station to deliver water to a set of new basins to be constructed on high ground a few miles outside the city.

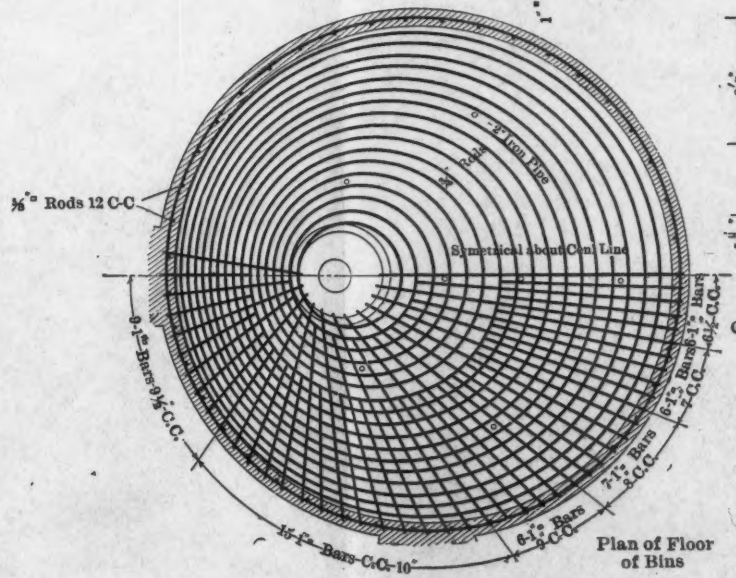
It was not until about 1901 that the Meramec project assumed a shape definite enough to attract sufficient attention to warrant a detailed investigation of its merits. It developed that this plan called for an expenditure of more than $30 000 000 and the abandonment of the existing pumping stations. As an alternative it was proposed to build a mechanical filtration plant to cost approximately $2 000 000, with an estimated cost of operation of $7.43 per 1 000 000 gal., amounting to an annual charge of about $200 000. In either case, aside from the expense, it would be a matter of years before the city could expect material improvement in the quality of its water supply.

Under the conditions thus briefly described, the present Water Commissioner assumed office in May, 1903. Work was started at once upon a plan designed for a system of flowing sedimentation, the settlement

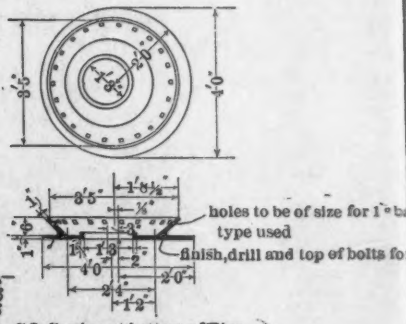




Plan of Roof of Bin
Detail subject to change



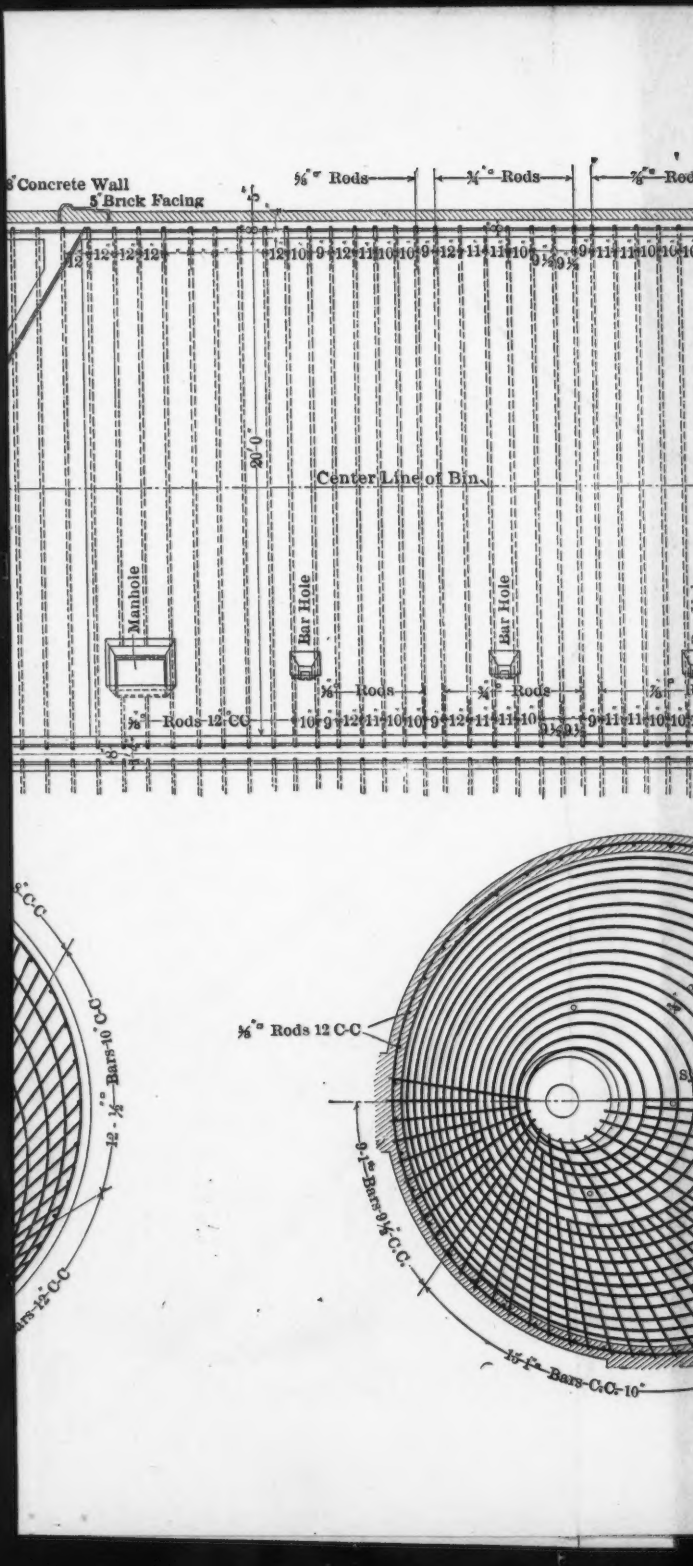
Plan of Floor of Bins

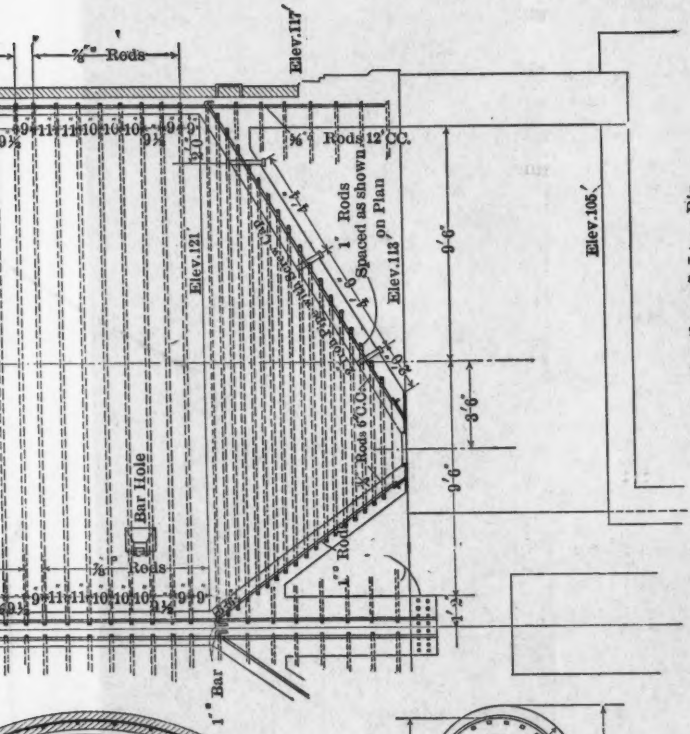


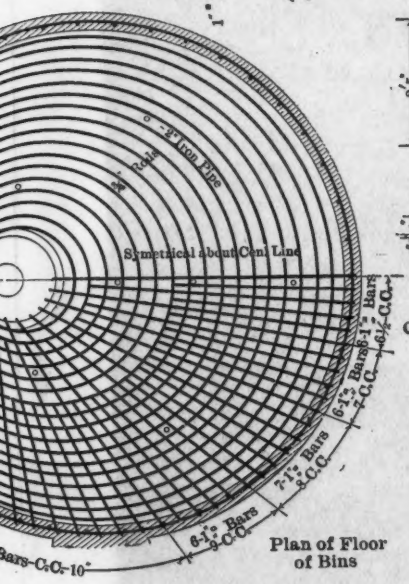
C.I. Casting at bottom of Bins

COAGULANT HOUSE

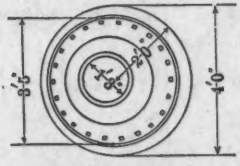
SECTIONS OF LIME BINS & DETAIL CHAIN OF ROCKS

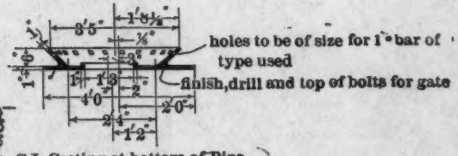

Concrete Wall
5" Brick Facing
⅝" Rods
¾" Rods
Center Line of Bin
20'-0"
Manhole
Bar Hole
Bar Hole
⅝" Rods
¾" Rods
⅞" Rods-12" CC
⅝" Rods 12 C-C
Bars-12 C-C
Bars-10" C-C
Bars-9½" C.C.
Bars-C.C.-10"





Plan of Floor of Bins





C.I. Casting at bottom of Bins

COAGULANT HOUSE

SECTIONS OF LIME BINS & DETAILS
CHAIN OF ROCKS

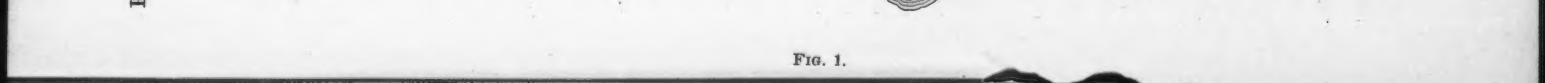


Fig. 1.

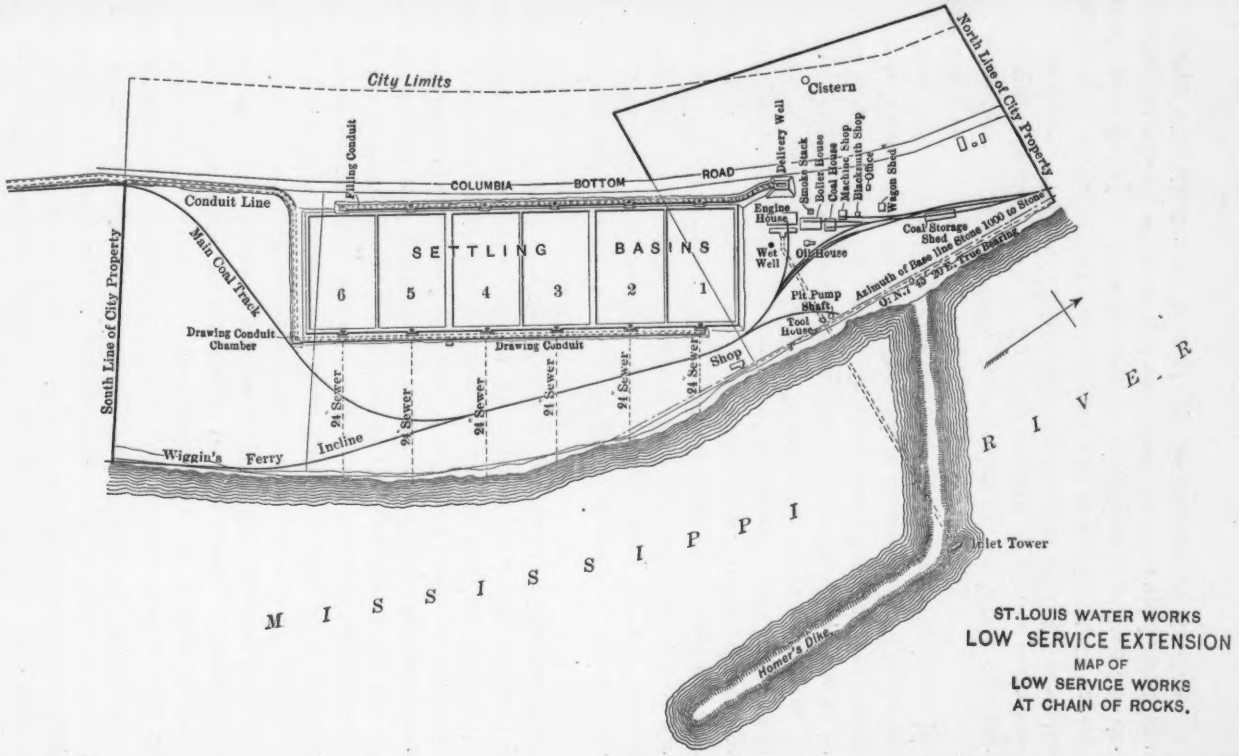

City Limits
North Line of City Property
Cistern
Filling Conduit
COLUMBIA
BOTTOM
ROAD
Delivery Well
Smoke Stack
Boiler House
Coal House
Machine Shop
Blacksmith Shop
Office
Wagon Shed
Engine House
Wet Well
Oil House
Coal Storage Shed
Stone 1000 to Stone
Azimuth of Base line
Conduit Line
Main Coal Track
SETTLING BASINS
6
5
4
3
2
1
Pit Pump Shaft
Tool House
Shop
Drawing Conduit Chamber
Drawing Conduit
South Line of City Property
24 Sewer
Incline
Wiggin's Ferry
RIVER
MISSISSIPPI
Inlet Tower
Homer's Dike
ST. LOUIS WATER WORKS
LOW SERVICE EXTENSION
MAP OF
LOW SERVICE WORKS
AT CHAIN OF ROCKS.

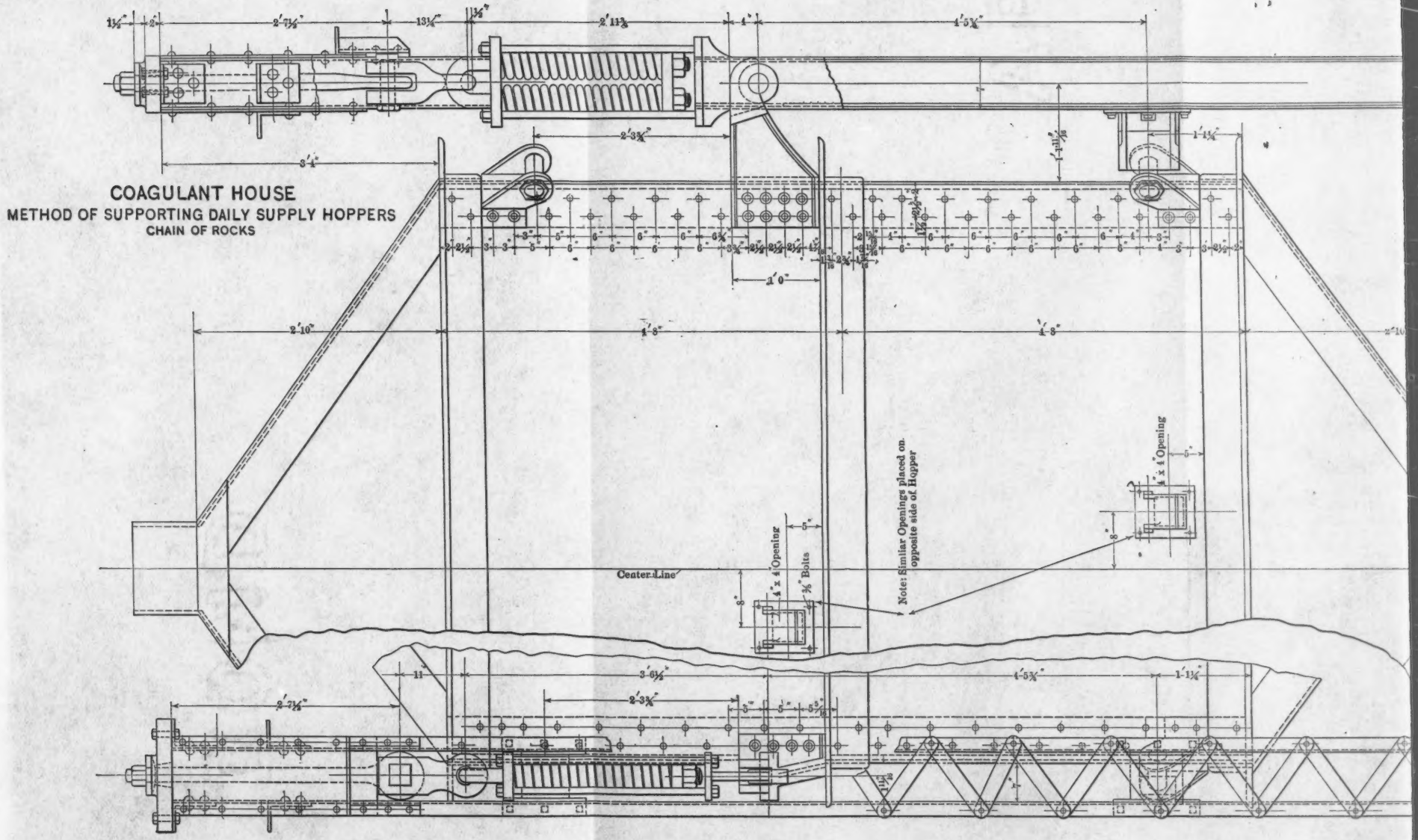
FIG. 1.

to be hastened by the use of some coagulant, presumably sulphate of alumina. This plan necessitated the cutting down of the walls separating the basins so as to form a series of weirs over which the water would flow in a thin sheet in passing from basin to basin. The weirs were 610 ft. in length, surfaced with brick, with baffles, for agitating and aerating the water, made by setting one course of brick on end. At the north end of the basins a receiving chamber, 610 ft. long, was built to distribute the water, at its entrance into the system of basins, over a weir, similar to the weirs between basins. This chamber was separated into two longitudinal compartments by a middle wall, perforated at the bottom with numerous openings about 3 in. high by 24 in. long. The water coming into the west end of the northern compartment, filled the southern compartment through the openings at the base of the middle wall and flowed evenly over the weir into the first basin. This chamber was designed with curved sides and bottom so that sediment would not accumulate and stop the passage of water through the small openings. In actual service this chamber admirably fulfilled the purposes for which it was designed, but, for reasons which developed later, its use was discontinued.

The original idea was to use sulphate of alumina as a coagulant, and to introduce it, in the form of a solution, along the weir between the first and second basin, through a submerged pipe lying along the upper side of the weir and discharging through small openings 2 or 3 ft. apart. A similar scheme for introducing a solution of sulphate of alumina into water for the purpose of aiding sedimentation was and had been in use at the Kansas City Water-works for several years.

The problem of removing the sediment from the basins was to be solved by using a floating dredge, designed somewhat after the models of those belonging to the Mississippi River Commission. The dredge had been built and used experimentally in the basins a year or so before this time.

Some time in August, 1903, the attention of the Water Commissioner was called to the use of lime and sulphate of iron as coagulants in conjunction with mechanical filters at Quincy, Ill. All available information on the subject was collected, and in October, 1903, experiments were started in the Laboratory of the Water Department to determine the relative efficiency and cost of the lime and sulphate-of-iron treatment with similar results produced by sulphate of alumina. In


COAGULANT HOUSE
METHOD OF SUPPORTING DAILY SUPPLY HOPPERS
CHAIN OF ROCKS
Center Line
Note: Similar Openings placed on opposite side of Hopper
4" x 4" Opening
⅞" Bolts

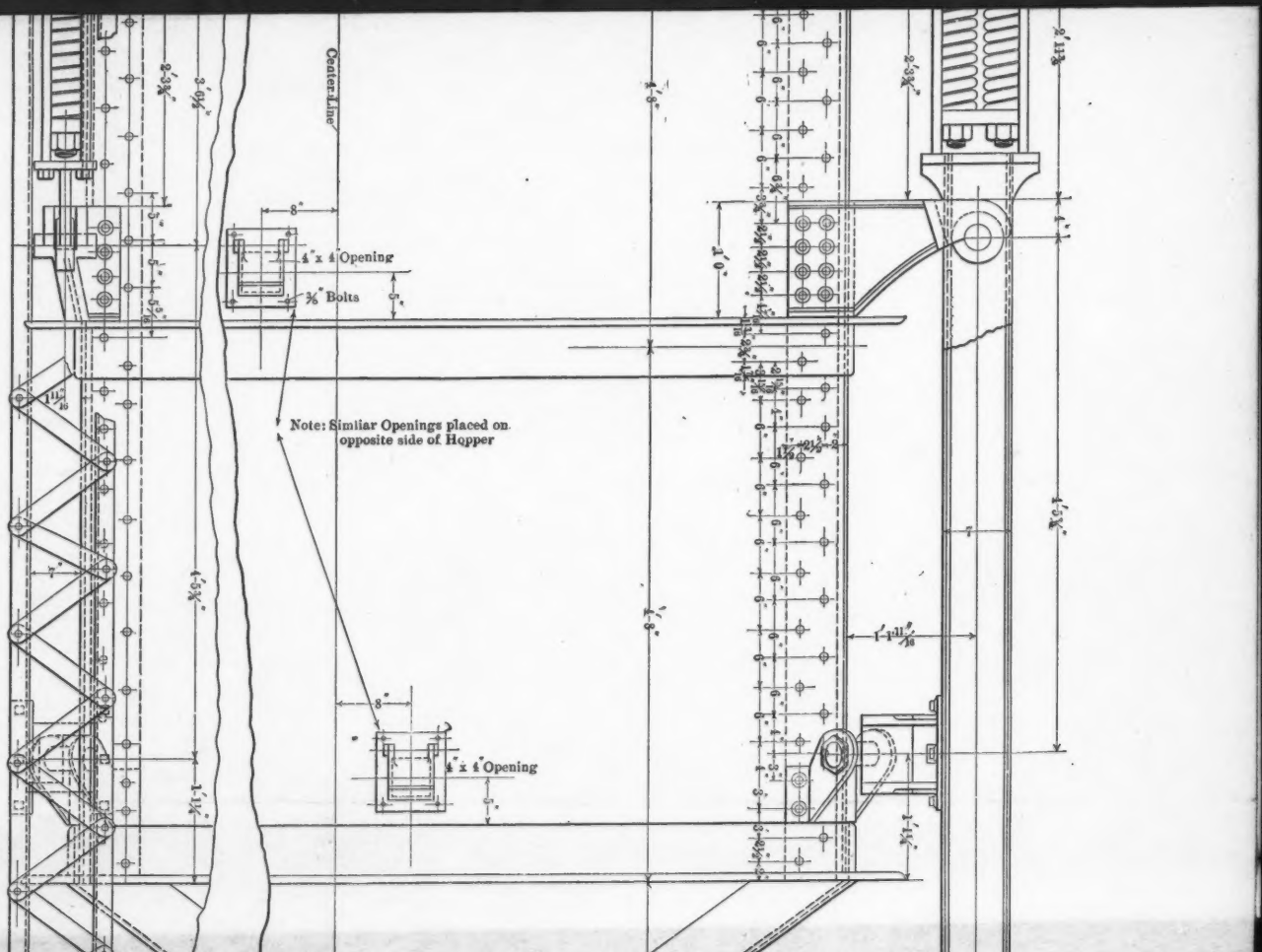
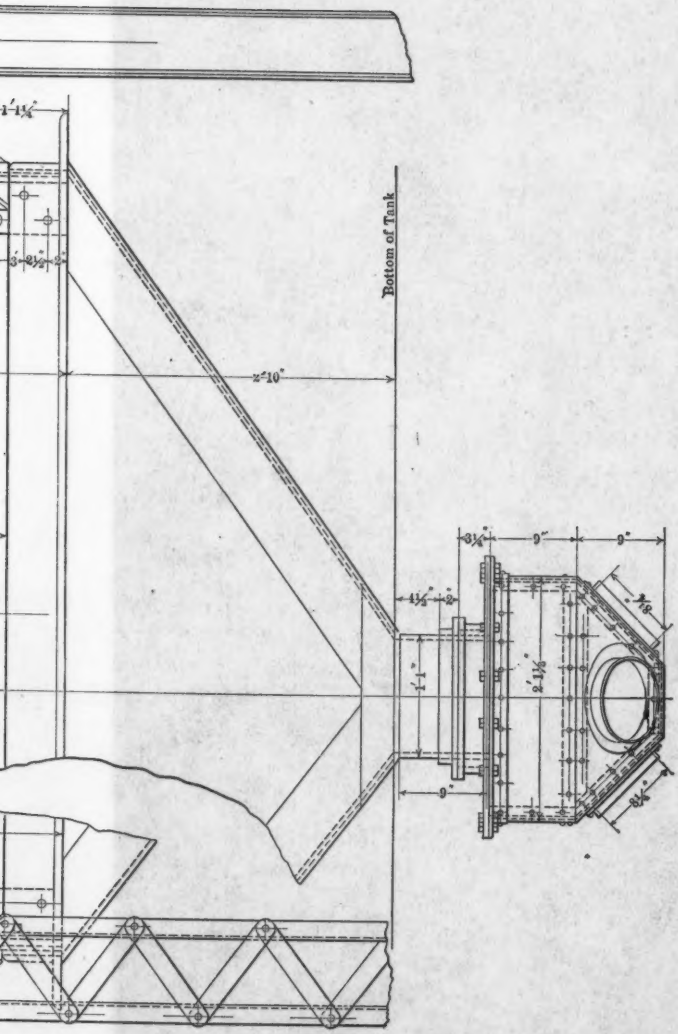

Center Line
8"
4"x 4" Opening
⅜" Bolts
Note: Similiar Openings placed on opposite side of Hopper
8"
4"x 4" Opening

PLATE LXXVII.
PAPERS, AM. SOC. C. E.
SEPTEMBER, 1907.
WALL ON
WATER PURIFICATION AT ST. LOUIS, MO.



a very short time there seemed to be no question of the superiority of the lime and sulphate-of-iron treatment in cost, efficiency and safety.

In November, 1903, the Water Commissioner and the writer visited the Quincy plant and were shown the practical application of the lime and sulphate-of-iron process in all its details. The action of these coagulants on the raw water on a large scale, was so exactly a reproduction of the Laboratory work, that the conclusion was inevitable that this process, modified to suit St. Louis conditions, would produce a wonderful improvement in the water supply.

Work was immediately begun on designing methods of application, of storing and handling chemicals, of changing projected plans to conform to later ideas, and of abandoning certain work already done. On March 22d, 1904, the plant was put in operation, and St. Louis has had no muddy water since, except on the few occasions when the operation of the plant has been interfered with by breakdown or accident.

The treatment consists in the addition of sulphate of iron and lime to the water in such quantities as are necessary to produce an efficient coagulation and a rapid subsidence of all suspended matter. The amount of sulphate of iron added varies from ½ gr. to 4 gr. per gal. of raw water, and the lime from 5 to 9 gr., depending on the quality of the raw water.

The Mississippi River water holds in solution bi-carbonate of lime and magnesia, free carbonic acid and sulphate of lime, all of which are reduced by the treatment except the sulphate of lime which is slightly increased on account of the action of the lime upon the sulphate of iron as follows:

$$Fe\,SO_4 + 7\,H_2O + CaH_2\,(CO_3)_2 = Fe\,H_2\,(CO_3)_2 + CaSO_4 + 7\,H_2O$$

The action of the lime is then as follows:

$$Fe\,H_2\,(CO_3)_2 + 2\,Ca\,(OH)_2 = Fe\,(OH)_2 + 2\;CaCO_3 + 2\,H_2O$$
$$CO_2 + Ca\,(OH)_2 = CaCO_3 + H_2O$$
$$Ca\,H_2\,(CO_3)_2 + Ca\,(OH)_2 = 2\,CaCO_3 + 2\,H_2O$$
$$Mg\,H_2\,(CO_3)_2 + 2\,Ca\,(OH)_2 = Mg\,(OH)_2\,CaCO_3 + 2\,H_2O$$

The ferrous hydrate, [$Fe\,(OH)_2$], remaining in the water oxidizes into ferric hydrate, thus:

$$2\,Fe\,(OH)_2 + H_2O + O = Fe_2\,(OH)_6.$$

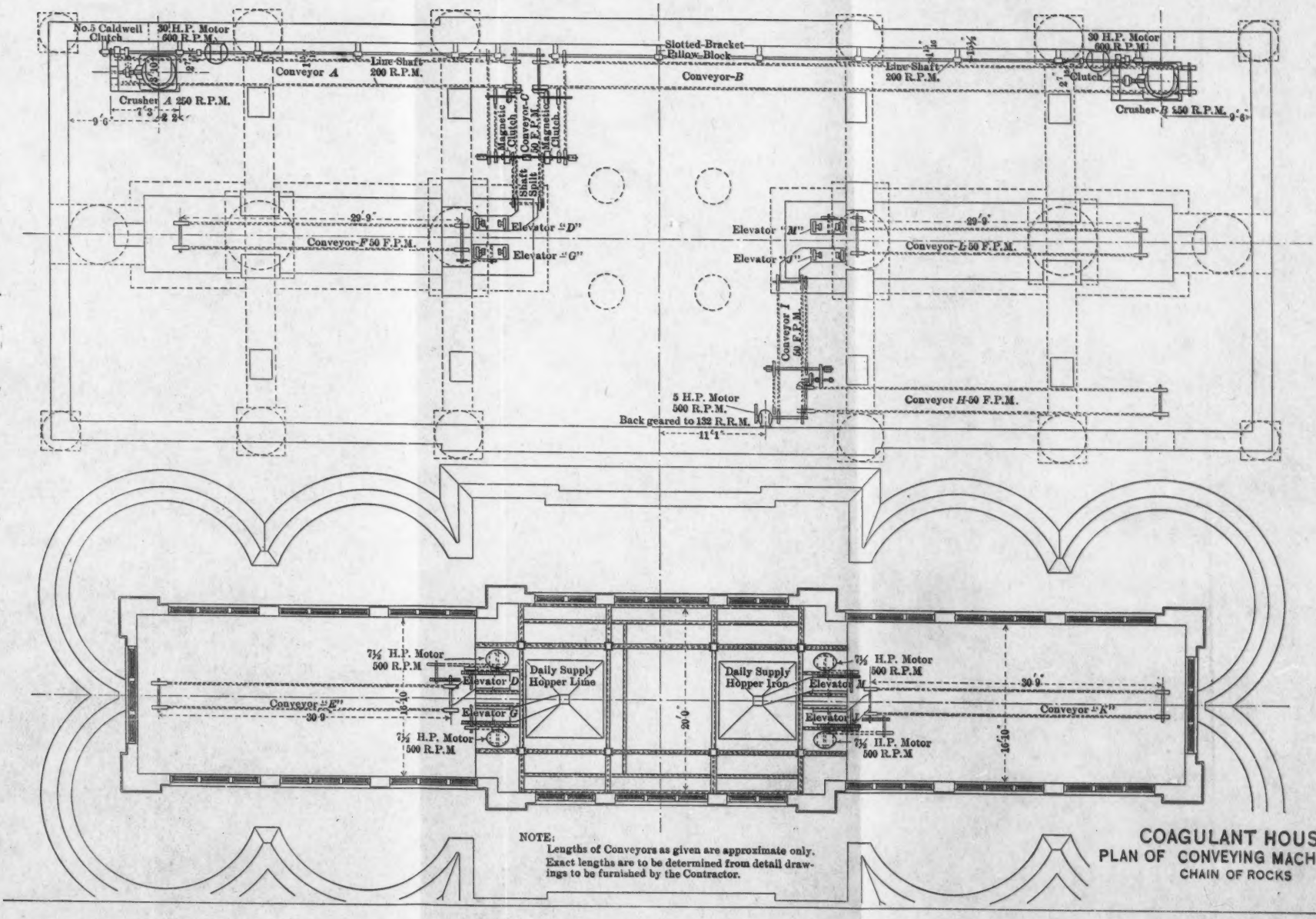
The normal carbonate of lime ($CaCO_3$), is only slightly soluble in water and crystallizes about the particles of suspended matter and on the flocculent precipitate of ferric hydrate, which also entangles portions of the suspended matter and serves to drag down the whole mass of matter in suspension, together with a very large percentage of the bacteria.

The hydrate of magnesia, $Mg(OH)_2$, precipitated, will settle out of the water slowly. It is insoluble, but as the water absorbs carbonic acid from the air, it will gradually be converted back into bi-carbonate of magnesia and again be taken into solution.

The original methods of applying the lime and sulphate of iron to the water, which have been considerably modified during the three years' operation, were the result of careful study and observation.

At Quincy, Ill., and at other places, the lime was reduced to a solution of lime-water and added in a constant quantity of known strength. To undertake to add the requisite quantity of lime, in the form of lime-water, to the raw water used in St. Louis, meant the reduction of from 30 to 40 tons of lime daily, which would necessitate a maximum capacity of about 10 000 000 gal. of lime-water. To manufacture such a quantity of lime-water every 24 hours would require an equipment of machinery and storage so large as to make the idea utterly impracticable, besides introducing other complications on account of the variations in strength of the lime-water due to temperature, which would require accurate and frequent determinations and changes in the measured quantities applied to the raw water. After a great many experiments it was decided to apply the lime in the form of milk of lime carrying from 5 000 or 6 000 gr. of lime per gal.

The method of manufacturing the milk of lime was as follows: Circular tanks, 6 ft. in diameter and 3 ft. deep, with revolving rakes to keep the hydrate of lime in suspension, were provided, and found to be capable of slaking 1 800 lb. of lime per hour each, when supplied with about 30 gal. of water per minute at a temperature of 120° fahr. The lime was added in weighed quantities to these tanks at 5-min. intervals, the weights corresponding to the number of gallons pumped per 5 min. multiplied by the number of grains per gallon added. This arrangement gave a continuous flow of milk-of-lime of practically constant strength, so long as the weight of lime added every 5 min. remained constant.



NOTE:
Lengths of Conveyors as given are approximate only. Exact lengths are to be determined from detail drawings to be furnished by the Contractor.

COAGULANT HOUSE
PLAN OF CONVEYING MACHINERY
CHAIN OF ROCKS

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The tanks for dissolving the sulphate of iron were 4 by 5 by 3 ft. deep, supplied with a continuous flow of cold water introduced at the bottom of the tanks through a number of ⅜-in. pipes with perforated caps, giving a network of horizontal streams over the bottom of the tank. The sulphate of iron was dumped into the tanks at 5-min. intervals, in weighed quantities corresponding to the gallons of water being pumped and the grains per gallon added.

The quantities of water supplied to the lime and sulphate-of-iron tanks may vary considerably, provided that so much water is not added as to produce a velocity high enough to carry small particles over in suspension, and also that, in the first case, enough water is supplied to each tank to convert the lime into a milk of lime which will flow readily, and, in the other, to dissolve the sulphate of iron entirely, since the proper weights of lime and sulphate of iron are added at 5-min. intervals.

The solution of iron sulphate is introduced into the water supply through an iron pipe leading down the uptake shaft, where it becomes thoroughly mixed with the river water in its passage to and through the pumps.

The milk of lime flows from the mixing tanks to a collecting tank, where it is diluted and cooled to about 100° fahr., whence it is pumped by a 20-h.p. centrifugal pump to the delivery well which receives the discharge from the low-service pumps. The milk of lime falling into this delivery well is mixed thoroughly with the water discharged from the pumps, which has already been treated with the sulphate of iron. By the time the water reaches the basin, coagulation has taken place, and the settlement begins as soon as the initial velocity of the entering water is sufficiently reduced. Fig. 2, Plate LXXXV, shows within what limited space this occurs.

Probably more than 90% of the suspended matter settles to the bottom of the basin into which the water is first introduced, and the degree of improvement in clarification produced by the journey of the water through the succeeding basins is not so marked, yet there is a vast difference between the quality of the water in the second basin and that in the sixth and last.

A long series of experiments was made in the attempt to determine the velocity of the water through the basins. The velocities are so low and the variations so great, the direction of currents so indeterminate

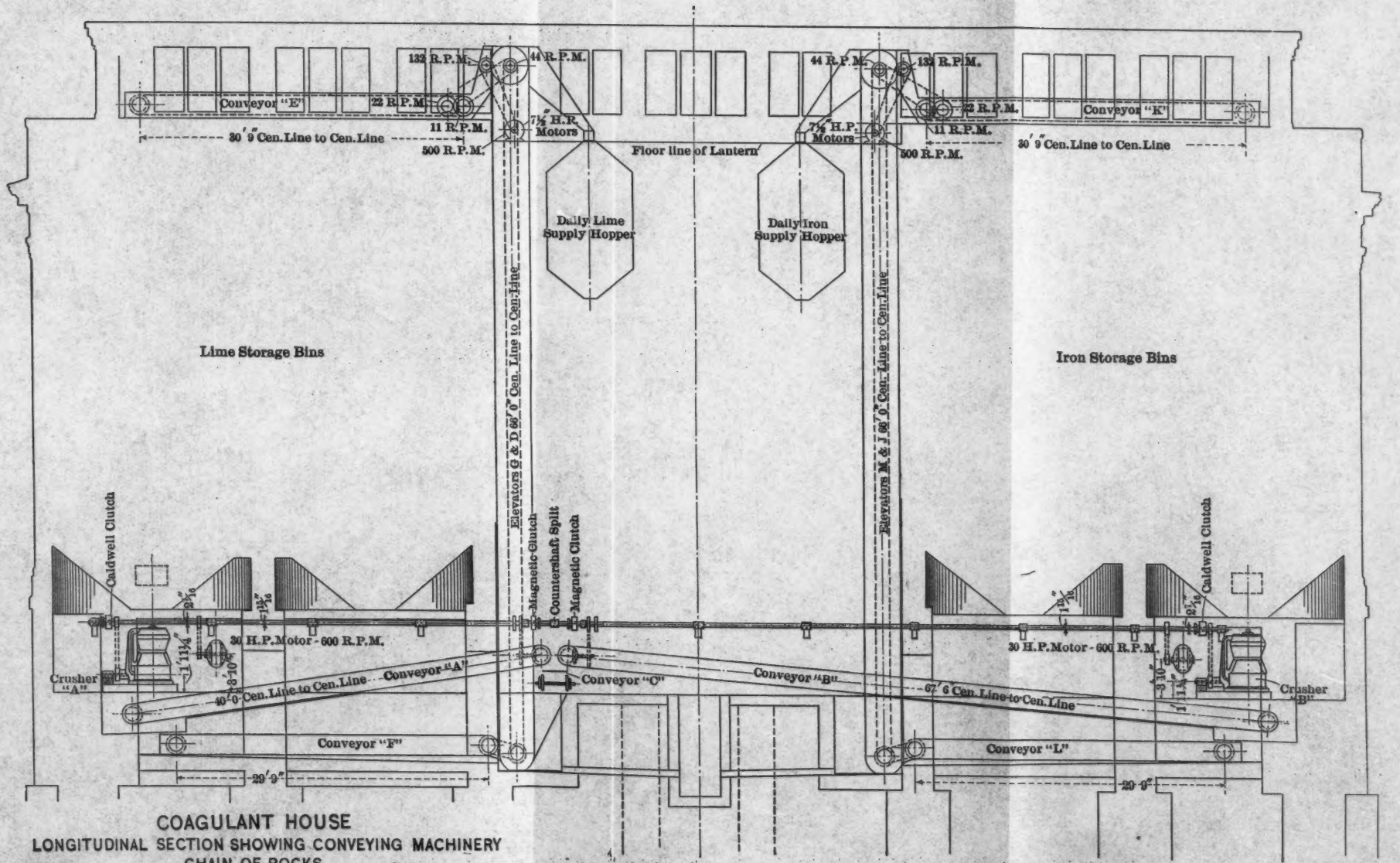
and so readily influenced by the wind, that it has been impossible to do more than to approximate roughly the velocities along the center line of the basins, the weather conditions being practically the same for all observations.

The following velocities are averaged from a number of observations, rod floats being used, the quantity of water passing through the basin at the time being at the rate of 70 000 000 gal. per 24 hours:

Float	submerged	6	in.,	velocity	5.35	ft.	per	min.
"	"	1	ft.	"	5.60	"	"	"
"	"	2	"	"	5.57	"	"	"
"	"	3	"	"	5.06	"	"	"
"	"	4	"	"	4.86	"	"	"
"	"	5	"	"	3.78	"	"	"
"	"	6	"	"	3.33	"	"	"
"	"	7	"	"	2.92	"	"	"
"	"	8	"	"	2.65	"	"	"
"	"	9	"	"	2.37	"	"	"
"	"	10	"	"	2.35	"	"	"

Floats of various designs were experimented with, for example, spherical surface floats of wood and of copper, double-ball floats, double floats with the upper float hemispherical and the lower one spherical, the two connected in one case by cotton cord, again by thin wire, and again by a small wooden rod, besides other forms and combinations. Fairly uniform results were obtained from the rod floats made of wood, 1§ in. in diameter. Observations taken by all other floats were so erratic that no use could be made of them.

Soon after this clarification process was put into operation, it was discovered that the agitation produced by the water flowing over the weirs was interfering with the sedimentation. The interference with the smooth flow of the water tended to break up the coagulated particles and to reduce them to such a state of fineness that sedimentation would not occur much more readily than in the raw water. This caused the abandonment of the use of the entrance chamber at the north end of the basins, and led to the practice of submerging all the weirs, so that the flow from basin to basin was smooth and uninterrupted. The water was introduced into Basin No. 1 through the gate connected with the filling conduit on the west side of that basin. These changes produced



COAGULANT HOUSE
LONGITUDINAL SECTION SHOWING CONVEYING MACHINERY
CHAIN OF ROCKS

Conveyors H and I (Iron Storage)
are not shown here



Fig. 2.

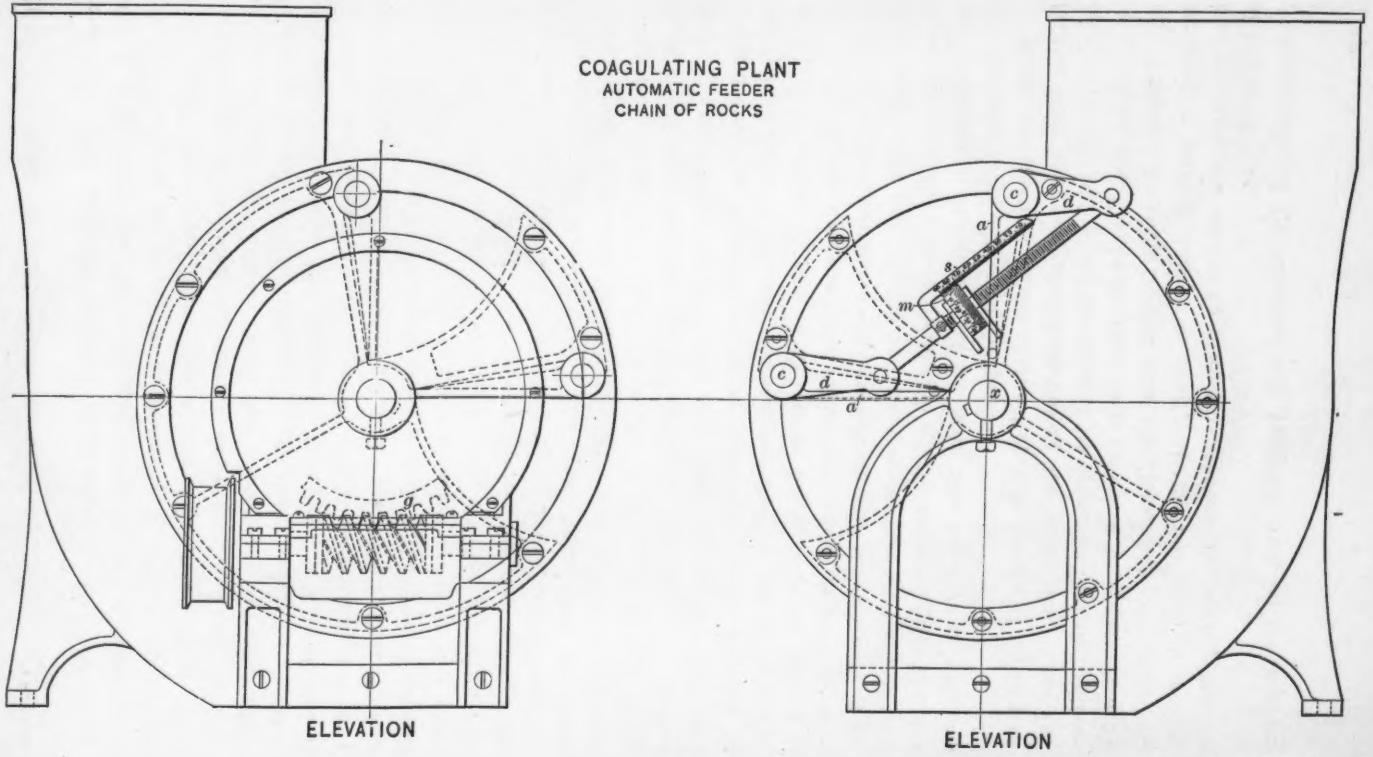
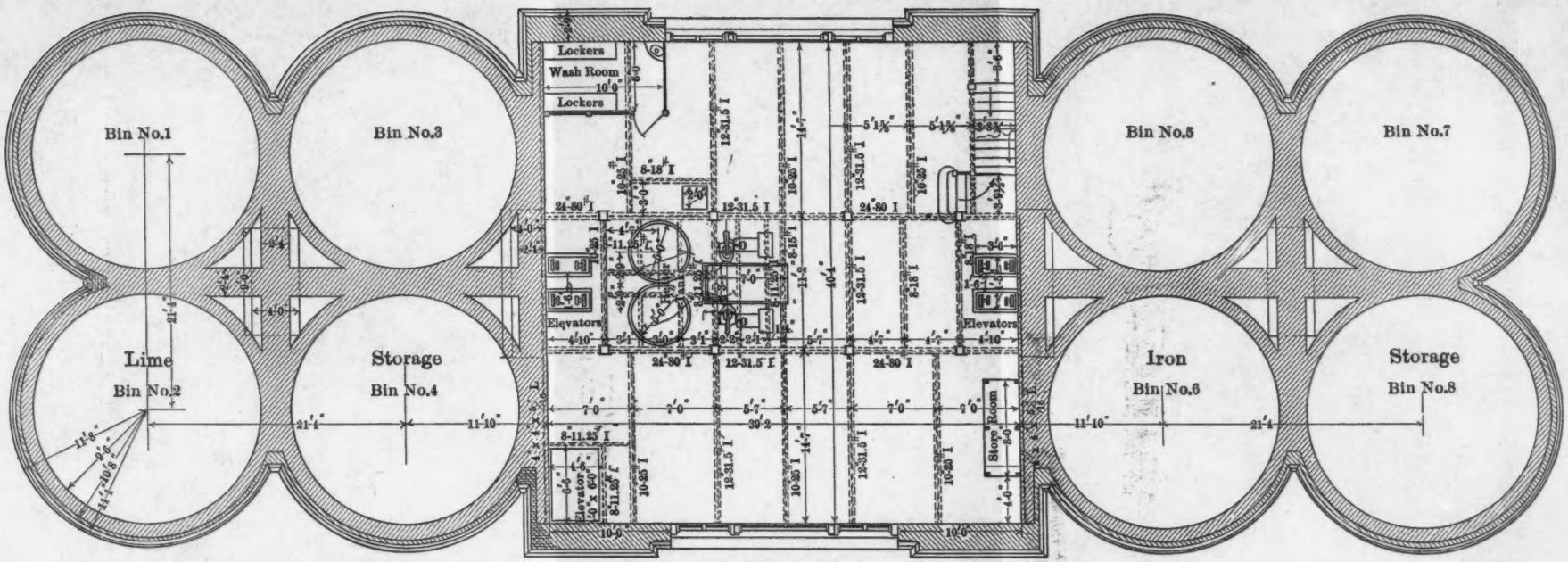

COAGULATING PLANT
AUTOMATIC FEEDER
CHAIN OF ROCKS
ELEVATION
ELEVATION

FIG. 2.

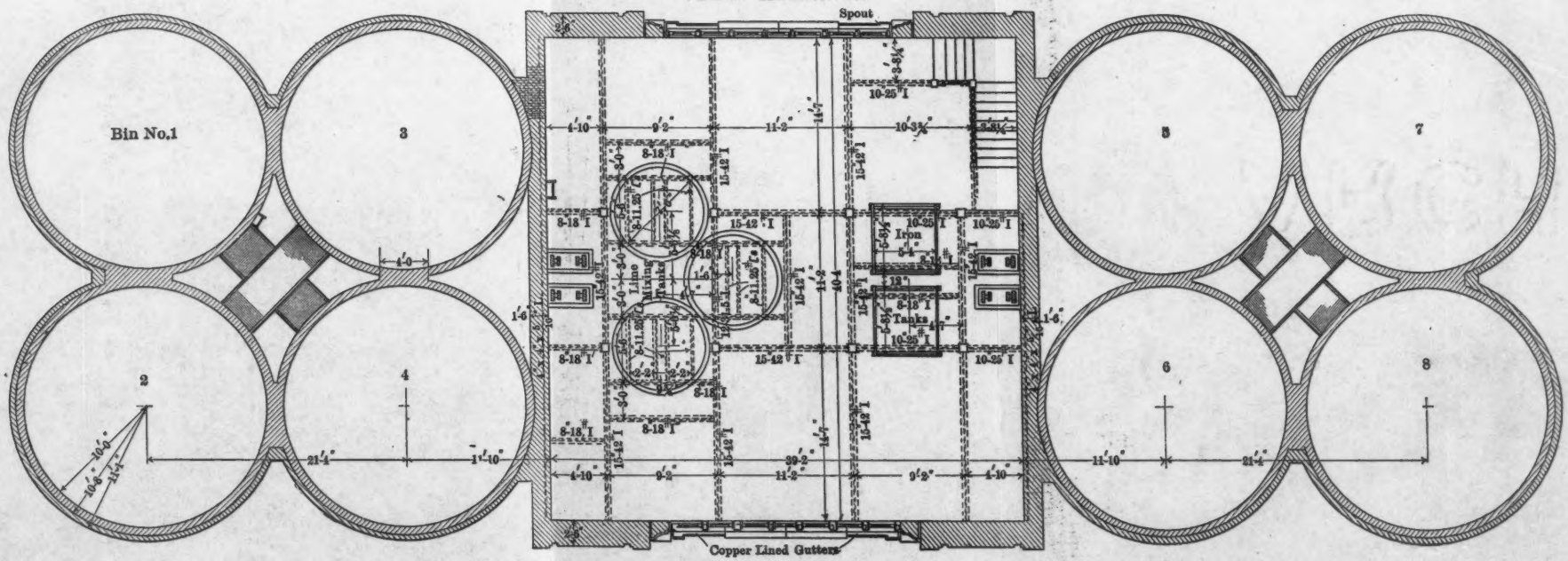
excellent results until the sediment accumulated in Basin No. 1 to such an extent that the inflow of water stirred up the deposited sediment and actually remuddied the clear water. To correct this a baffle was built in front of the inflow pipes of Basins No. 1 and No. 6. This baffle brought all the incoming water to the surface and kept the currents at or near the surface. With this arrangement the basin could be kept in service until the sediment accumulated within a few inches of the top of the baffle. By opening the sewer gate on the east side of the basin, and leaving it open until the effluent became almost clear, a vast quantity of mud was washed out of the basin daily, thus allowing it to be kept in service for much longer periods without being emptied and cleaned. When it finally became necessary to empty and clean Basin No. 1, the water was introduced from the filling conduit into Basin No. 6 through the west gate, reversing the flow through the basin and drawing the clear water from Basin No. 2, while Basin No. 1 was emptied and cleaned. Basin No. 1 was then filled with clear water over the weir from Basin No. 2, and the clear water supply was drawn from Basin No. 1 until Basin No. 6 had to be cleaned, when the flow was again reversed and the operation resumed as in the first case. It soon became apparent that only these two basins would need frequent cleaning under this system of operation, whereas formerly all the basins had to be regularly cleaned, necessitating the constant employment of a force of men in the basins for about seven months of the year. It has developed that these end basins require cleaning after two or three months' service, depending upon the character of the river water. The cost of cleaning is not more than one-third of what it was under the old system, although all the sediment plus the lime and iron sulphate is deposited in the basin now, while 75 or 80% only was deposited there under the old system.

While the practical results obtained by this process of water purification have been very gratifying during the entire time it has been used, it is only within the last year of its operation that the methods, the working, and the results have been subjected to systematic study and analysis. Previous to that time the Department was kept fully occupied in making changes to rectify glaring faults which required neither study nor science to discover, although the remedy was not always so obvious.

Practically all the chemical and bacterial work on the raw and



PLAN AT ELEVATION 118



PLAN AT ELEVATION 130

COAGULANT HOUSE

PLANS AT PUMP AND MIXING FLOORS

CHAIN OF ROCKS.

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treated water during the first two years of operation was done outside of the Department by the City Chemist and the City Bacteriologist, and under the direction of the Board of Health.

TABLE 1.—AVERAGE PERCENTAGES AND REDUCTION BY MONTHS.

Date.	SUSPENDED SOLIDS. P. P. M.		DISSOLVED SOLIDS. P. P. M.		BACTERIA, PER CUBIC CENTIMETER.		
	River.	Tap.	River.	Tap.	River.	Tap.	% Removal.
April, 1904	2 400	130	189	160	126 500	22 940	86.0
May, 1904	1 548	65	206	161	57 000	5 850	93.0
June, 1904	3 372	39	206	165	27 000	1 050	96.0
July, 1904	2 483	48	212	144	26 000	323	98.7
August, 1904	1 290	40	257	170	15 180	817	95.0
September, 1904	1 000	15	228	177	14 200	225	98.2
October, 1904	460	13	301	194	.....	.....	.....
November, 1904	228	9	320	195	24 300	4 050	82.5
December, 1904	256	9	352	227	48 250	4 587	90.5
January, 1905	79	16	414	242	20 000	1 857	90.7
February, 1905	29	4	406	280	39 350	1 341	96.5
March, 1905	942	9	225	180	33 700	1 910	94.4
April, 1905	440	6	206	156	66 080	2 200	96.8
May, 1905	965	30	273	234	15 130	900	94.0
June, 1905	1 040	15	231	158	32 310	619	98.4
July, 1905	2 606	41	233	182	91 000	1 750	98.2
August, 1905	1 746	24	216	165	40 400	400	99.0
September, 1905	1 125	16	218	185	32 400	350	98.9
October, 1905	730	15	224	156	53 820	390	99.3
November, 1905	395	10	248	155	46 250	1 863	96.0
December, 1905	388	10	316	186	48 520	848	98.4
January, 1906	496	7	231	151	144 420	1 810	98.7
February, 1906	259	0	247	144	47 220	1 164	97.5
March, 1906	858	3	166	118	66 560	202	99.7

Special tests, taking daily samples for from 10 days to 2 weeks, for the purpose of determining the presence of *B. Coli Communis* have been made at various times and by different observers. Except in one or two doubtful cases the total absence of *B. Coli* in the tap water was established beyond any reasonable doubt.

Table 2 shows the improvement in the purity of the water supply in a marked degree.

The population of St. Louis, in 1900, was 575 000, in round numbers; in 1907, it is 700 000. The record for 1904 must be read, bearing in mind that the purification process was not started until April and that 1904 was the year of the World's Fair in St. Louis, which temporarily increased the population by many thousands, and, under the conditions prevailing in previous years, an increase in the number of cases and deaths from all diseases could reasonably have been expected.

TABLE 2.—CASES AND DEATHS FROM TYPHOID FEVER IN ST. LOUIS, SINCE JANUARY 1ST, 1900.

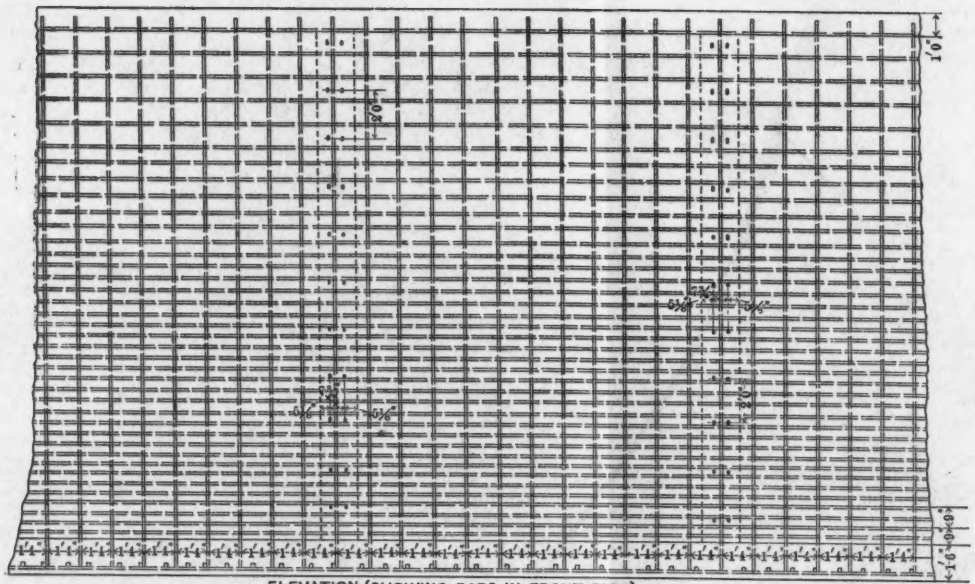
Months.	1900.		1901.		1902.		1903.		1904.		1905.		1906.		1907.	
	C.	D.	C.	D.	C.	D.	C.	D.	C.	D.	C.	D.	C.	D.	C.	D
January	57	19	76	8	103	14	81	15	65	19	20	5	28	7	12	5
February	42	5	55	14	52	16	55	15	37	7	14	6	17	5	15	6
March	117	16	32	11	34	11	91	20	61	20	19	4	18	6	14	2
April	34	4	24	4	48	14	79	17	38	12	18	1	17	5	....	....
May	29	4	32	8	38	11	86	15	56	18	32	9	12	3	....	....
June	26	8	26	6	28	7	90	16	25	6	15	6	14	3	....	....
July	43	15	49	13	83	14	189	26	65	23	59	18	50	8	....	....
August	119	20	185	31	88	26	221	37	178	30	130	24	154	16	....	....
September	253	13	138	24	169	21	261	42	180	36	163	17	125	29	....	....
October	262	30	205	32	194	32	183	30	99	24	105	23	101	14	....	....
November	127	15	154	27	169	31	131	23	44	17	63	7	50	11	....	....
December	104	19	125	20	106	25	119	31	24	13	36	6	24	5	....	....
Totals	1 213	168	1 101	198	1 112	222	1 586	287	872	225	674	126	610	112	....	....

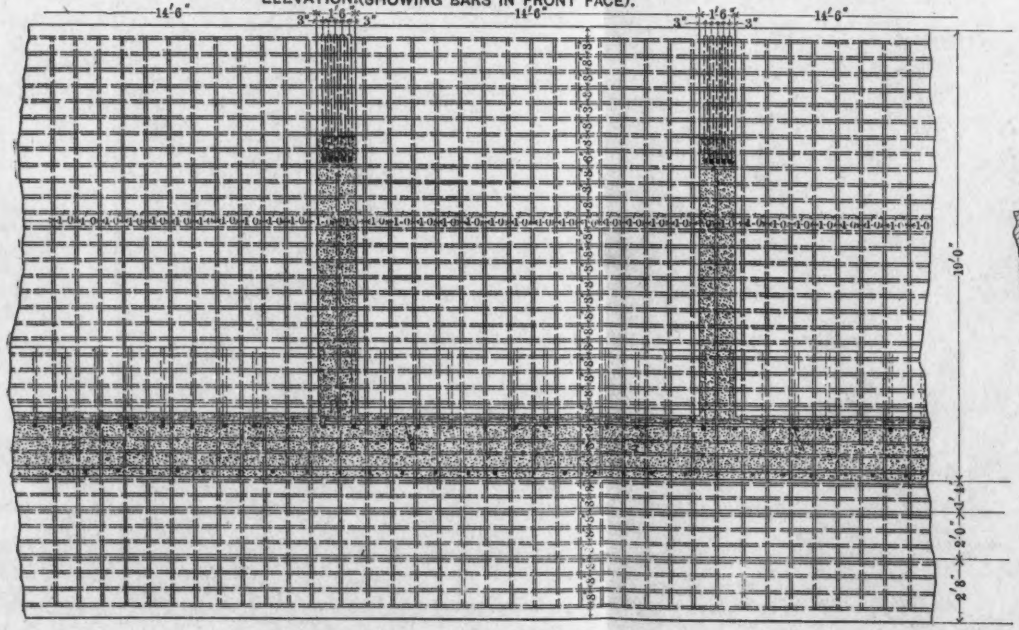
The typhoid rate was 29.4 per 100 000 in 1900, increasing to more than 40 per 100 000 in 1903, and then decreasing to 16 per 100 000 in 1906. This, in itself, does not express the total beneficial effect on the general health arising from the use of pure water. Allen Hazen, M. Am. Soc. C. E., estimates that where one death from typhoid has been avoided through an improved water supply, probably two or three deaths from other diseases have been avoided. The following record seems to indicate a higher proportion of decrease than Mr. Hazen's estimate would give:

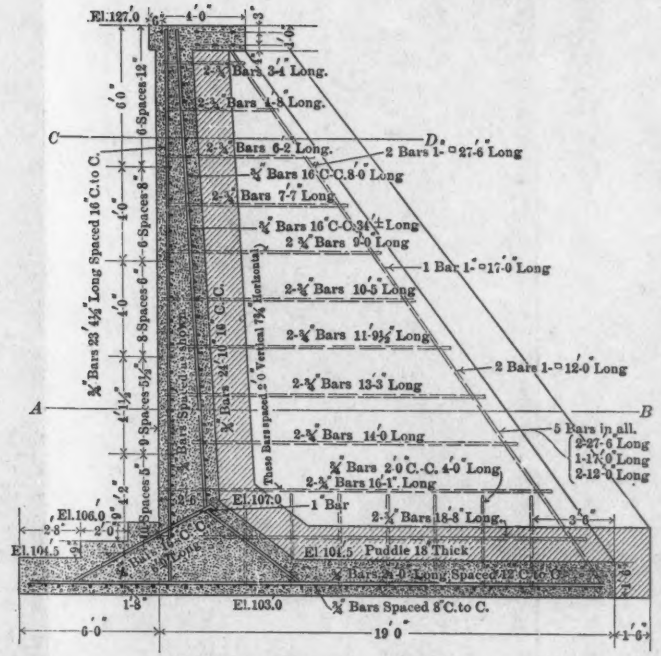
ANNUAL MORTALITY RECORD, ST. LOUIS, MO., 1900 TO 1906, FROM DISEASE ALONE:

1900	9 217	1904	10 695
1901	9 916	1905	9 545
1902	9 654	1906	9 214
1903	10 320		

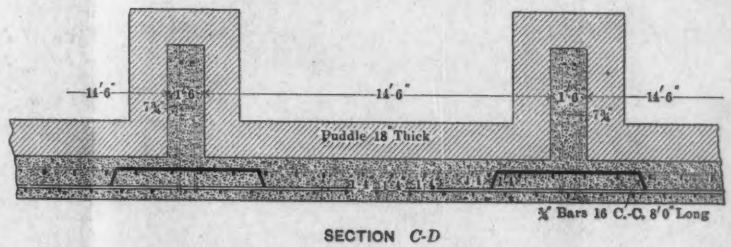
The original method of preparing both the iron solution and the milk of lime was not entirely satisfactory from the first. The iron solution, as it came from the tank, varied in strength at times as much as 25% from the normal, due to adding the charges at 5-min. intervals while the stream of water flowing through the mass was constant. Evidently as the mass dissolved toward the end of the 5-min. period, less







GENERAL SECTION OF WEST WALL.



SECTION *C-D*

LOW SERVICE EXTENSION

BASINS 7 AND 8

ELEVATION & SECTIONS OF WALL.



sulphate of iron would be exposed to the water, and the solution would be weaker. The extent of variation could be limited by reducing the water supply to the minimum quantity necessary to keep the sulphate dissolved approximately as fast as added, but a simpler and more certain way of maintaining a constant strength solution would be by feeding the sulphate to the tank continuously and evenly. The sulphate of iron is shipped in bulk and is known as "sugar" sulphate. It is similar in fineness to granulated sugar, and when perfectly dry will flow like dry sand. The physical condition of the sulphate is not uniform enough to allow of the use of a standardized orifice, so that it became necessary to design an apparatus for automatic force feeding, which would ensure the measurement of equal volumes, in equal times, and be susceptible of adjustment to various rates of feeding. The range of the apparatus must cover all rates from 2½ to 50 lb. per min.

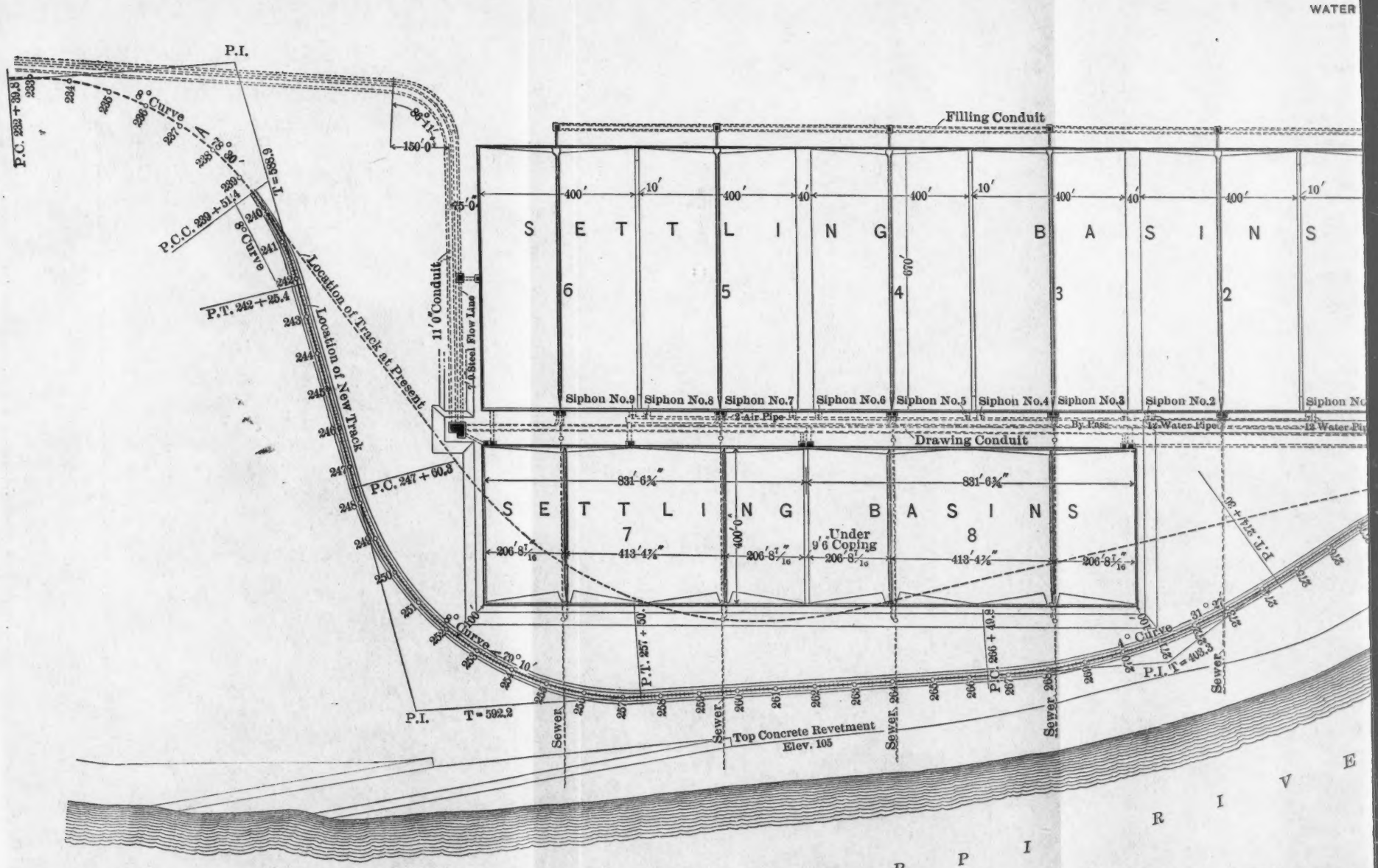
The machine shown on Fig. 2 was designed and built in the Department, and when operated its measurements were found to be absolutely uniform. The machine consists of a cylinder about 12 in. in diameter and 5 in. long, with two pockets whose size may be varied by the movement of the side, *a*, which revolves about *C* as a center. This adjustable side fits closely to the ends of the cylinder and to the curved side of the pocket. These adjustable sides are moved by the arms, *d*, *d*, which, in their turn, are moved by the micrometer screw, *m*, while the positions of the movable sides are shown by the scale, *s*. The cylinder revolves on the axis, *x*, and is driven by the worm gearing, *g*. The cylinder is partially covered by a casing which serves to hold the full load in the pockets until they reach the position for dumping, and also to prevent the escape of material from the hopper. The cylinder revolves at a constant speed, about 12 rev. per min., and measures and discharges a constant volume of material in equal periods of time.

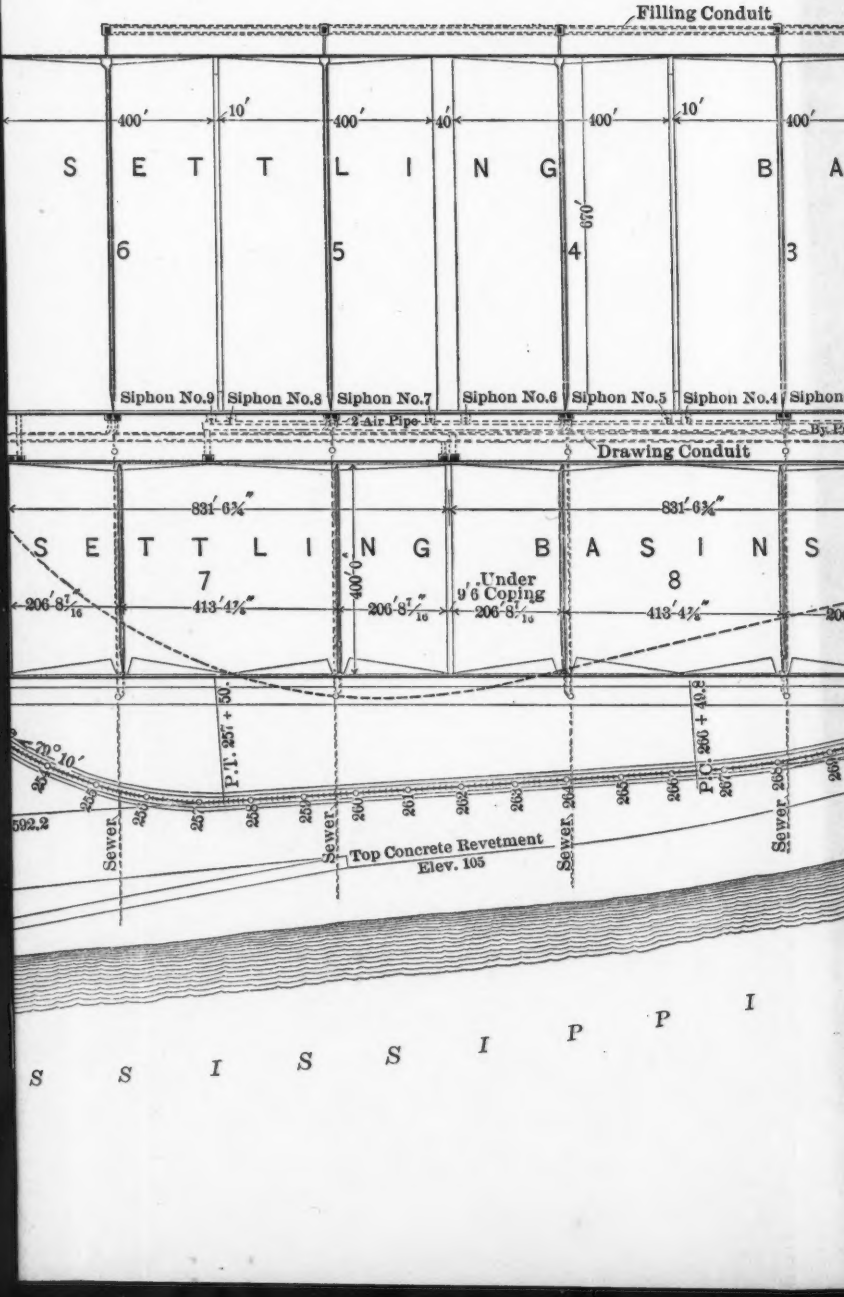
Tests made to determine the available amount of calcium hydrate carried by the milk of lime, as manufactured by the system of tanks described heretofore, showed that there occurred a heavy loss, amounting at times to as much as 35% of the theoretical value of the quicklime weighed into the tanks. About 3% of this loss is due to impurities in the quicklime, such as sand, dirt, flint and underburned stone. Another portion of loss is due to the air-slaking of the quicklime

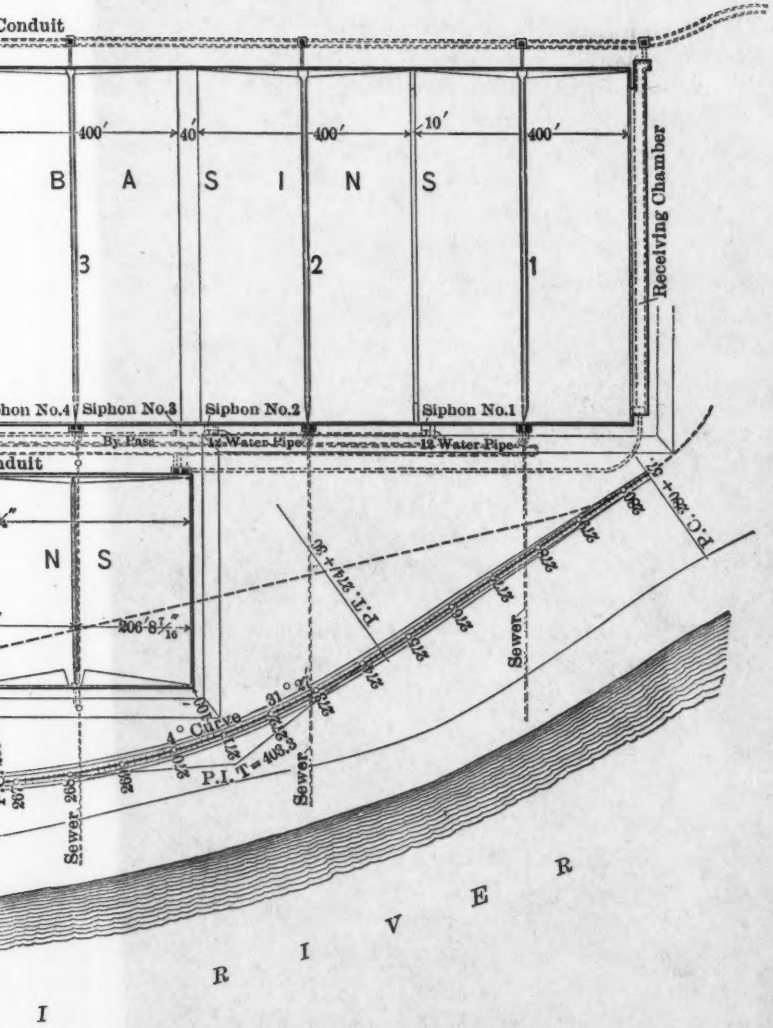
in transit and in storage. In very warm, moist weather this loss is considerable, but during the greater part of the year it is very small. The greatest part of the loss was found to be due to imperfect hydration, small particles of unslaked lime being carried out of the tanks in suspension. Lowering the velocity through the tanks by reducing the quantity of water, at 120° fahr., supplied to them, increased the efficiency and raised the temperature of the tank contents. Increasing the temperature of the water supplied to the tanks from 120° to 150° fahr., without cutting down the quantity, resulted in an increased efficiency of about 15% and raised the temperature in the tanks to almost 200° fahr.

By supplying the tanks with a quantity of water (at 50° fahr.) approximately equal by weight to three times the weight of quicklime added, complete hydration resulted with a tank temperature of more than 200° fahr. This was unsatisfactory because the tank contents became too thick to flow readily through the outlet pipe, and, if not constantly watched, would eventually become so stiff as to stop the stirring apparatus. An addition of too much cold water would reduce the temperature of the tank contents too low for efficient hydration. This led to the idea of utilizing the heat of the effluent from the tanks for heating the water supply. This was accomplished by the addition of an auxiliary tank into which the milk of lime is conducted from the several slaking tanks. This auxiliary tank contains a coil through which the cold water flows on its way to a head tank, from which the supply is piped to the slaking tanks. The head tank is equipped with a float valve to regulate the flow of incoming water, so that a constant head is kept on all the feed pipes leading to the slaking tanks. Each feed pipe has, at its lower end, an adjustable orifice to regulate the quantity of water supplied to each tank, so that the quantity of water entering each tank is from 3½ to 3¾ times as much by weight as the lime added to that tank. The temperature of the tank contents is over 200° fahr., and that of the water in the head tank about 100° fahr., varying with the temperature and quantity of the cold water entering the coils. This arrangement has been in service for several months and has shown a decided reduction in the expense of operation.

The total quantities of sulphate of iron and lime used during the first year of operation were: 3 578 tons of sulphate of iron, and 14 291 tons of lime; during the second year: 4 138 tons of sulphate of iron,


WATER
P.I.
P.C. 233 + 30.3
8° Curve
T = 638.9
P.C.C. 239 + 51.4
8° Curve
P.T. 242 + 25.4
Location of Track at Present
Location of New Track
P.C. 247 + 60.3
8° Curve
70° 10'
P.I.
T = 592.2
150'0"
45'0"
11'0" Conduit
7'0 Steel Flow Line
Filling Conduit
SETTLING BASINS
400'
10'
40'
670'
6
5
4
3
2
Siphon No.9
Siphon No.8
Siphon No.7
Siphon No.6
Siphon No.5
Siphon No.4
Siphon No.3
Siphon No.2
2 Air Pipe
By Pass
12 Water Pipe
Drawing Conduit
SETTLING BASINS
831'6¼"
7
8
Under 9'6 Coping
400'0"
206'8 7/16"
413'4⅞"
206'8 7/16"
206'8 7/16"
413'4⅞"
206'8 7/16"
P.T. 257 + 50.
P.C. 296 + 40.2
4° Curve
P.I. T = 403.3
Sewer
Top Concrete Revetment
Elev. 105
MISSISSIPPI RIVE
LOW SERVIC
BASINS
LOCATI


Filling Conduit
400′
10′
400′
40′
400′
10′
400′
S E T T L I N G B A
670′
6
5
4
3
Siphon No.9
Siphon No.8
Siphon No.7
Siphon No.6
Siphon No.5
Siphon No.4
Siphon
2 Air Pipe
Drawing Conduit
831′ 6¾″
831′ 6¾″
S E T T L I N G B A S I N S
7
8
400′ 0″
Under 9′ 6 Coping
206′ 8 7/16″
413′ 4 7/8″
206′ 8 7/16″
206′ 8 7/16″
413′ 4 7/8″
P.T. 257 + 50.
P.C. 260 + 40.3
70° 10′
Sewer
Sewer
Sewer
Sewer
Top Concrete Revetment
Elev. 105
S S I S S I P P I



LOW SERVICE EXTENSION

BASINS 7 AND 8

LOCATION PLAN



and 11 814 tons of lime; during the third year: 4 050 tons of sulphate of iron, and 14 081 tons of lime.

The total quantity of water treated during the first year was 33 133 million gal.; during the second year, 26 334 million gal.; and during the third year 26 682 million gal.

The average daily consumption of water has not increased proportionately with the population since the clarification of the water supply.

The population of the city has increased from 575 000 in 1900 to 700 000 in 1907. The average daily water consumption for each year during this period follows:

1900-01	63 000 000 gal.
1901-02	67 173 000 "
1902-03	66 211 000 "
1903-04	69 916 000 "
1904-05	79 052 000 "
1905-06	69 000 000 "
1906-07	70 109 000 "

The average quantities of sulphate of iron and lime used during the first year were 1.5 gr. of sulphate of iron and 6.0 gr. of lime per gallon of water treated; during the second year, 2.2 gr. of sulphate of iron and 6.28 gr. of lime; during the third year, 2.13 gr. of sulphate of iron and 7.39 gr. of lime.

The average cost per 1 000 000 gal. of water treated (including labor and power) for the first year was $3.60, for the second year, $3.99 and for the third year, $4.62. The cost in detail is as follows:

	1904-05	1905-06	1906-07
Cost of lime	$1.89	$1.74	$2.45
Cost of sulphate of iron	1.07	1.53	1.44
Labor	0.57	0.62	0.58
Power	0.07	0.09	0.07
Repairs	....	0.01	0.08
	$3.60	$3.99	$4.62

The gradual increase in the cost of purification is due to several causes. During the first year we were proceeding cautiously and often

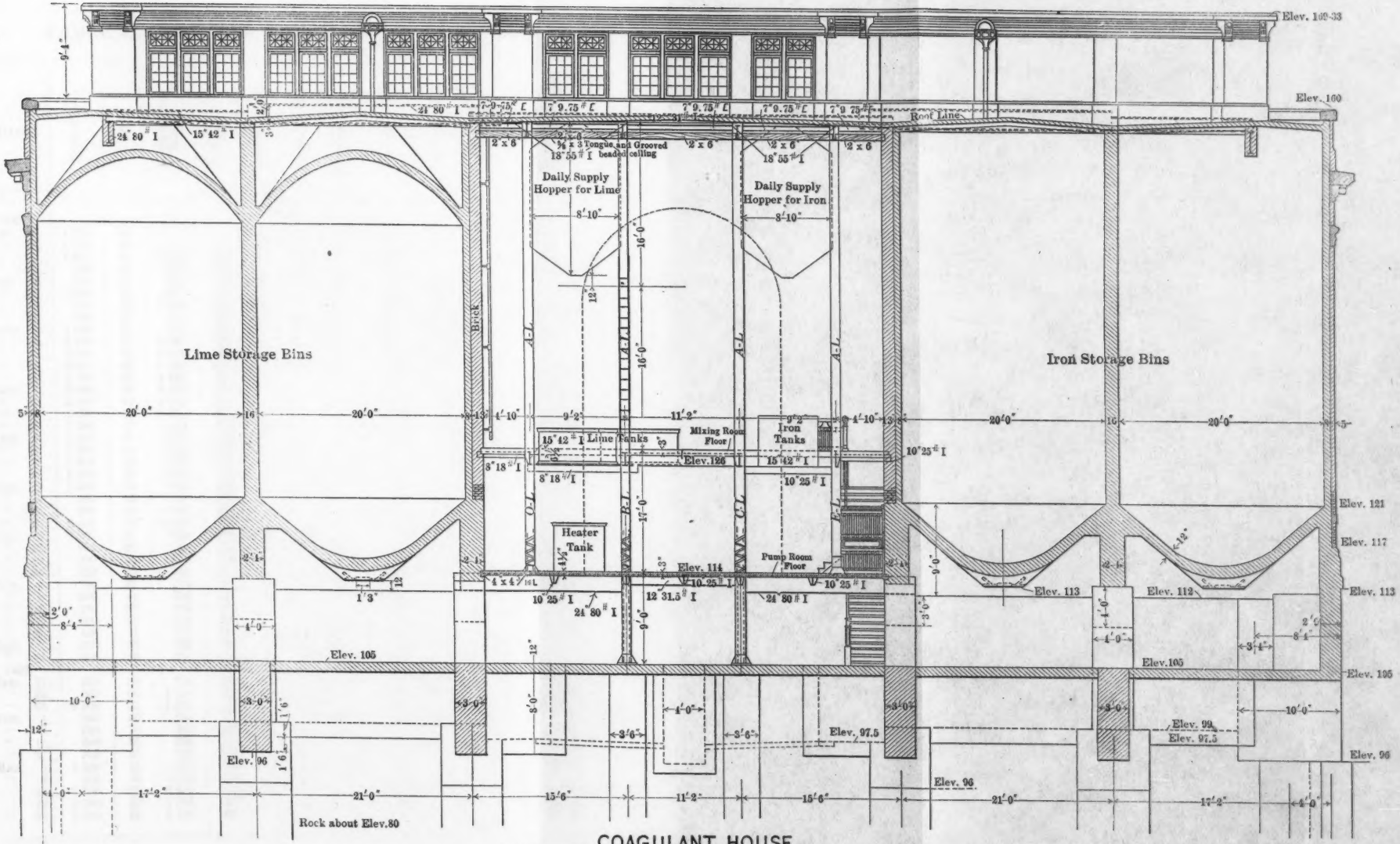
used quantities (both of sulphate of iron and of lime) too small to produce efficient coagulation and settlement. The water as drawn from the settling basins was often turbid and nearly always cloudy. It was not until the latter part of the first year that the efficiency of the treatment began to approach the results which were obtained during the third year. We were also afraid of having caustic lime in the effluent, and, at that time, had not devised any definite method of determining the quantity of lime which it would be safe to add, and in trying to avoid the error of using too great a quantity, we naturally fell into the mistake of adding too little. The increase in cost per 1 000 000 gal. during the third year was due principally to the fact that the price of lime was raised from $3.88 to $4.65 per ton. The average quantity of lime added, in grains per gallon, was greater during the third year on account of the longer period of very turbid water in the river, and because of greater accuracy in proportioning the proper quantity of lime necessary each day and a consequent production of a continuous supply of pure and clear water.

Tables 3 and 4 give comparative analyses of the river and treated water, showing the reduction of bacteria and tests for *B. Coli Communis*. The bacterial tests were not started until November, 1906, on account of delay in equipping the laboratory with the necessary apparatus.

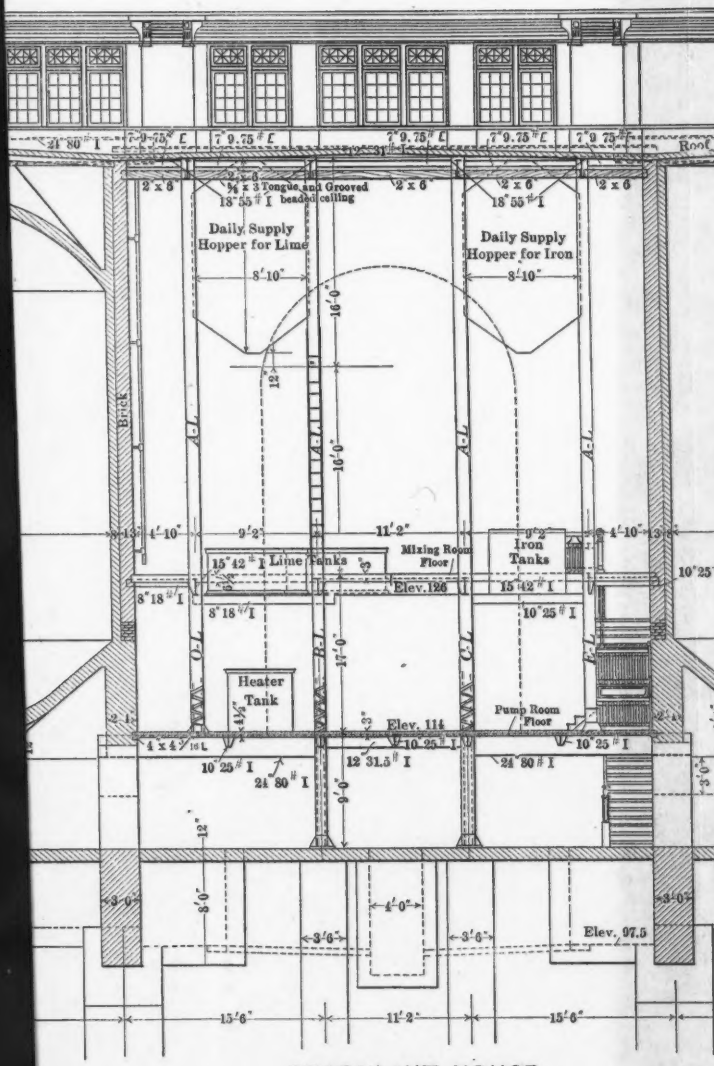
The maximum quantity of sulphate of iron added to the water on any occasion during the third year was 3.75 gr., the minimum being 1.25 gr. per gal. of water treated; of lime, the maximum was 11 gr., and the minimum, 3 gr. per gal. of water treated. These figures are calculated on the weights of sulphate of iron and lime as taken from the bins, but, in the case of the lime, the actual efficient quantity is much less than the record shows, on account of deterioration in transit and in storage from air-slaking; for example, in the case of the 11 gr. mentioned, the actual amount of efficient lime, as determined by analysis, was 7.7 gr. This explains why the average for the year in grains per gallon is as high as 7.39; the average of efficient lime added would be considerably lower. The sulphate of iron does not deteriorate appreciably in storage.

The alkalinity of the treated water during the third year varied from 35 to 75 parts per million, the average being 49. The increase of incrustants through the action of the sulphate of iron averaged 13

PLATE LXXXIII.
PAPERS, AM. SOC. C. E.
SEPTEMBER, 1907.
WALL ON
WATER PURIFICATION AT ST. LOUIS, MO.

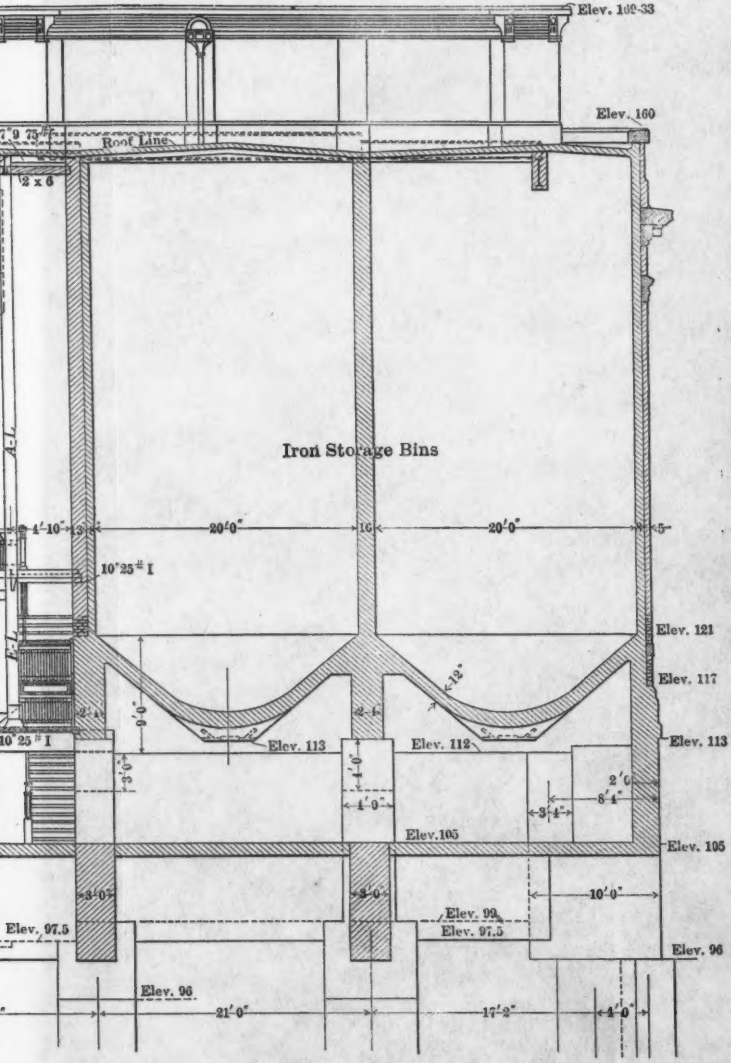


COAGULANT HOUSE
LONGITUDINAL SECTION THROUGH CENTER OF BINS.
CHAIN OF ROCKS



COAGULANT HOUSE
LONGITUDINAL SECTION THROUGH CENTER OF BINS.
CHAIN OF ROCKS

PLATE LXXXIII.
PAPERS, AM. SOC. C. E.
SEPTEMBER, 1907.
WALL ON
WATER PURIFICATION AT ST. LOUIS, MO.



ER OF BINS.



TABLE 3.—ANALYSES OF RIVER WATER, ST. LOUIS, MO.

DATE.	Turbidity.	Color.	Suspended Solids.	Dissolved Solids.	Calcium Ions.	Magnesium Ions.	Sulphate Ions.	Alkalinity.	Incrustants.	Neutral Carbonates.	CO_2	Bacteria, per cubic centimeter.
1906.												
Apr. 6..	1 650	45	.....	.....	33	13	19	90	22	.....	1	.....
" 13..	1 000	59	.....	.....	28	10	12	106	.....	.....	2	.....
" 20..	1 800	51	1 116	210	36	12.6	20	120	22	.....	3	.....
" 27..	500	45	319	189	30	9.5	30	112	.....	.....	2	.....
May 4..	180	51	108	150	32	8.3	25.3	98	17	.....	1	.....
" 11..	1 200	35	671	206	41	10.4	33	126	22	.....	2	.....
" 18..	800	35	1 008	246	52	12	41	143	36	.....	2	.....
" 25..	800	31	711	289	45	15	53	148	28	.....	1	.....
June 1..	1 050	35	842	281	45	11.1	44	140	20	.....	1	.....
" 8..	2 400	31	2 090	264	46	11.5	74	134	28	.....	3	.....
" 15..	3 000	31	3 910	263	42	11.5	74	137	16	.....	3	.....
" 22..	3 600	35	5 080	273	41	10.8	69	133	15	.....	2	.....
" 29..	3 600	31	4 220	291	44	13.4	80	134	32	.....	4	.....
July 6..	3 000	35	3 402	263	.....	.....	.....	128	.....	.....	3	.....
" 13..	2 400	41	2 084	244	.....	.....	.....	118	.....	.....	2	.....
" 20..	1 500	35	1 673	246	.....	.....	.....	120	.....	.....	2	.....
" 27..	1 500	41	1 493	218	35	12	76	128	20	.....	1	.....
Aug. 3..	1 500	31	1 267	272	44	13	80	129	34	12	.....	.....
" 10..	1 350	35	966	238	.....	.....	.....	130	.....	.....	.....	.....
" 17..	1 500	35	1 225	213	.....	.....	.....	130	.....	.....	.....	.....
" 31..	1 800	35	1 654	218	.....	.....	.....	130	.....	2	.....	.....
Sept. 7..	1 350	40	850	243	42	12	55	134	20	10	.....	.....
" 14..	900	35	720	223	.....	.....	.....	137	.....	6	.....	.....
" 21..	900	35	627	246	.....	.....	.....	143	.....	14	.....	.....
" 28..	2 400	35	1 367	225	.....	.....	.....	135	.....	.....	1	.....
Oct. 5..	1 050	41	849	201	37	12.5	47	119	25	.....	2	.....
" 12..	900	35	750	248	45	13.6	56	141	29	.....	1	.....
" 19..	900	35	670	293	.....	.....	.....	152	.....	.....	2	.....
" 26..	550	35	412	314	.....	.....	.....	165	.....	8	.....	.....
Nov. 2..	700	35	771	313	56	16.6	71	174	36	14	.....	26 900
" 9..	900	41	558	294	54	17	69	166	40	8	.....	35 400
" 16..	750	59	497	288	.....	.....	.....	158	.....	10	.....	42 000
" 23..	500	63	444	284	.....	.....	.....	156	.....	12	.....	32 300
" 30..	400	71	371	290	.....	.....	.....	165	.....	12	.....	20 700
Dec. 7..	450	65	362	280	48	17.8	43	165	28	12	.....	.....
" 14..	300	45	231	304	52	16.3	48	170	28	10	.....	.....
1907.												
Jan. 11..	450	35	354	296	53	14.6	48	164	38	.....	.....	25 900
" 18..	600	60	1 269	219	34	15.8	38	120	31	.....	2	20 400
" 25..	1 800	45	1 817	138	.....	.....	.....	67	.....	6	.....	87 800
Feb. 1..	500	55	630	169	24	9.7	25	90	10	0	2	46 600
" 8..	250	70	212	220	38	15	48	135	11	6	4	25 800
" 15..	200	35	386	246	.....	.....	.....	168	.....	.....	3	18 200
" 21..	800	35	492	290	.....	.....	.....	158	.....	.....	3	.....
Mar. 1..	1 500	45	1 700	230	42	11	62	140	10	.....	5	85 800
" 8..	900	45	1 088	248	40	15	48	132	31	.....	4	48 700
" 15..	1 500	70	2 006	216	34	12	51	110	24	.....	2	88 200
" 22..	1 500	50	1 905	275	.....	.....	.....	146	.....	.....	3	26 100
" 29..	1 200	30	1 190	267	.....	.....	.....	142	.....	.....	2	12 900

TABLE 4.—WATER ANALYSES, CLEAR WELL AT BISSELL'S POINT.

DATE.	Color.	Suspended Solids.	Dissolved Solids.	Calcium Ions.	Magnesium Ions.	Sulphate Ions.	Alkalinity.	Incrustants.	Caustic Alkalinity.	Bacteria, per cubic centimeter.	Removal, per cent.
1906.											
April 6	20	.....	.....	25	5.8	22	37	48	5	.....	.....
" 13	10	.....	.....	24	3.6	55	37	37	3	.....	.....
" 20	12	3.6	150	20	2.9	55	40	21	0	.....	.....
" 27	12	5.2	146	28	4.1	46	42	45	6	.....	.....
May 4	10	10.0	110	22	5.0	32	46	29	7	.....	.....
" 11	12	27.2	151	24	3.8	69	40	36	6	.....	.....
" 18	12	10.0	155	25	4.3	60	43	37	1	.....	.....
" 25	14	7.6	190	21	6.4	64	44	40	0	.....	.....
June 1	10	0.0	160	22	5.0	44	39	36	1	.....	.....
" 8	12	5.6	184	26	3.8	87	39	42	3	.....	.....
" 15	12	5.2	201	31	2.3	83	40	46	6	.....	.....
" 22	10	4.4	208	36	1.7	83	45	52	15	.....	.....
" 29	10	6.0	246	41	1.2	90	52	54	20	.....	.....
July 6	10	5.8	263	.....	.....	.....	51	.....	15	.....	.....
" 13	10	6.4	215	.....	.....	.....	53	.....	15	.....	.....
" 20	10	4.4	212	.....	.....	.....	55	.....	21	.....	.....
" 27	12	5.6	187	25	4.8	80	47	34	3	.....	.....
Aug. 3	12	2.4	192	23	6.0	87	48	35	0	.....	.....
" 10	10	0.0	180	.....	.....	.....	41	.....	0	.....	.....
" 17	10	2.4	160	.....	.....	.....	.....	.....	0	.....	.....
" 31	10	7.6	147	.....	.....	.....	45	.....	1	.....	.....
Sept. 7	10	3.6	159	18	4.8	66	46	19	0	.....	.....
" 14	10	1.2	168	.....	.....	.....	47	.....	5	.....	.....
" 21	10	1.6	169	.....	.....	.....	50	.....	2	.....	.....
" 28	12	3.6	171	.....	.....	.....	50	.....	0	.....	.....
Oct. 5	15	3.6	155	25	5.8	56	52	34	4	.....	.....
" 12	10	3.6	170	22	7.2	80	53	32	0	.....	.....
" 19	10	3.2	182	.....	.....	.....	59	.....	0	.....	.....
" 26	10	4.0	194	.....	.....	.....	57	.....	1	.....	.....
Nov. 2	10	2.8	206	21	12.5	77	59	45	0	2 600	90.0
" 9	12	1.6	209	21	11.8	71	56	46	2	2 000	94.3
" 16	10	3.2	196	.....	.....	.....	55	.....	0	5 000	85.7
" 23	10	0.4	196	.....	.....	.....	58	.....	0	600	98.1
" 30	10	4.0	197	.....	.....	.....	60	.....	2	1 200	94.2
Dec. 7	8	5.6	192	21	14.5	53	60	52	0	.....	.....
" 14	10	4.4	186	20	13.0	48	58	47	0	.....	.....
" 21	8	3.2	194	.....	.....	.....	62	.....	0	.....	.....
" 28	8	0.0	210	.....	.....	.....	68	.....	0	.....	.....
1907.											
Jan. 4	8	0.0	222	.....	.....	.....	75	.....	0	.....	.....
" 11	8	6.0	193	21	12.5	56	64	39	0	330	98.7
" 18	8	1.2	191	22	15.0	48	56	60	0	935	95.4
" 25	12	0.0	135	.....	.....	.....	51	.....	17	20	99.9
Feb. 1	12	8.4	130	22	7.9	33	48	37	0	1 200	97.4
" 8	12	1.2	138	21	10.0	55	52	34	0	160	99.4
" 15	12	1.6	148	.....	.....	.....	56	.....	0	.....	.....
" 21	10	0.8	181	.....	.....	.....	61	.....	0	.....	.....
Mar. 1	10	2.0	179	21	10.0	73	51	45	11	00	100.0
" 8	12	4.8	171	19	11.0	64	43	59	0	50	99.9
" 15	12	4.8	165	20	11.0	66	41	56	0	40	99.9
" 22	10	0.4	175	.....	.....	.....	39	.....	1	50	99.8
" 29	10	0.0	181	.....	.....	.....	43	.....	0	40	99.7



FIG. 1.—RECEIVING CHAMBER, NORTH SIDE OF BASIN NO. 1, AS ORIGINALLY BUILT.

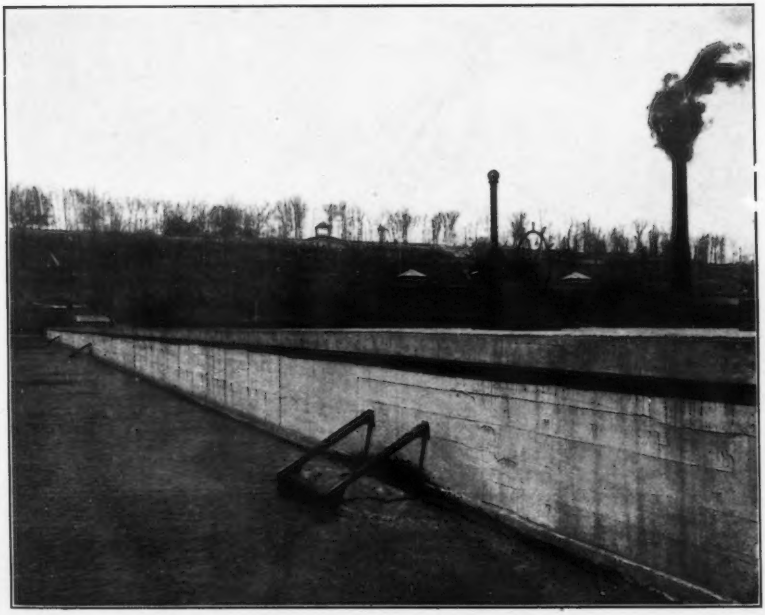


FIG. 2.—RECEIVING CHAMBER REMODELED TO INTRODUCE WATER INTO BASIN NO. 1 THROUGH FOUR 3 BY 3-FT. GATES.

parts per million, calculated as calcium carbonate. The softening actually accomplished by the treatment is a reduction of the lime carbonate to 53% of that in the raw water, and of the magnesia to 57%; the average of 204 determinations each, of the amounts of calcium and magnesium in the raw water, were 42.3 and 13.1 parts per million, respectively; in the treated water, 22.8 and 7.54 parts per million.

TABLE 5.—PERCENTAGE OF REDUCTION IN BACTERIA AS THE WATER PASSES THROUGH THE BASINS:

	Basin No. 1.	Basin No. 2.	Basin No 3.
October, 1906	76.4%	82.8%	.....
November, 1906	89.0%	90.0%	90.1%
December, 1906	72.2%	77.5%	67.8%
January, 1907	93.7%	96.0%	97.4%
February, 1907	96.0%	98.4%	99.0%
March, 1907	96.1%	99.1%	99.8%

During each day as often as conditions require, samples are taken from each basin, and the caustic alkalinity of each sample determined by titration. Throughout the basins the caustic alkalinity is kept as low as is consistent with efficient coagulation, the aim being to keep down the charge of lime until the last basin shall show little or no caustic alkalinity. It is not possible to maintain any uniform set of conditions throughout the basins on account of the great and sudden fluctuations in the quality of the river water. The quantity of lime added being controlled in this way, the changes in the amount of sulphate of iron necessary are determined from the appearance of the coagulation and from the condition of the water in each basin, turbidity determinations being made from a portion of the samples taken for testing the caustic alkalinity.

Determinations of the turbidity, color, etc., of the raw water and of the water in the basins are carried on daily, a record being kept as shown in Table 6.

The coagulating plant which has been in use for more than three years was originally built as a temporary affair, with the expectation that it would be replaced by a permanent structure after the World's Fair in 1904. The cost of this temporary coagulant plant, with all machinery and connections, was less than $10 000. The cost of changing the settling basins, necessary to put in operation the purification scheme, amounted to about $25 000.

TABLE 6.—LABORATORY RECORD, CHAIN OF ROCKS, ST. LOUIS, MO.

1907.		River Water.						Grains, per Gallon.		Entrance.		Basin No. 1.		Basin No. 2.		Basin No. 3.		Basin No. 4.		Bas'n No. 5.		Basin No. 6.		Wind.	
April.																									
Day.	Hour.	Stage.	Temperature.	Turbidity.	Color.	CO_2	Alkalinity	Lime.	Iron.	Color.	Caustic.	Color.	Caustic.	Color.	Caustic.	Color.	Caustic.	Color.	Caustic.	Color.	Caustic.	Color.	Caustic.	Direction.	
1	8 A. M.	88.9	55°	1 200	35	3	132	6.5	2.25	14	8	14	7	12	8	12	5	12	2	12	3	10	4	N. E.	Mild.
	9 "	.....	.....	.....	.....	.....	.....	6.0	2.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	10:30 "	.....	.....	.....	.....	.....	.....	6.0	2.0	14	2	14	4	12	5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	1 P. M.	.....	.....	.....	.....	.....	.....	6.0	2.0	14	1	14	2	12	4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3:30 "	.....	.....	.....	.....	.....	.....	6.0	2.0	16	2	14	2	14	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	8 A. M.	89.2	54°	1 500	45	3	132	6.25	2.25	16	4	14	0	14	—1	14	—1	12	1	12	1	12	1	S.	Brisk.
	9 "	.....	.....	.....	.....	.....	.....	6.75	2.25	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3	8 "	89.2	55°	1 500	45	3	128	6.75	2.25	14	4	14	4	12	5	12	4	12	2	12	1	10	1	S.	Brisk.
	10 "	.....	.....	.....	.....	.....	.....	6.75	2.25	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3:30 P. M.	.....	.....	.....	.....	.....	.....	6.75	2.25	14	7	14	6	12	4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
4	8 A. M.	89.0	56°	1 500	35	3	122	6.75	2.25	14	6	14	6	12	7	12	6	12	6	12	5	10	5	W.	Mild.
	3 P. M.	.....	.....	.....	.....	.....	.....	6.25	2.0	14	1	12	7	12	9	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
5	8 A. M.	88.9	6°	1 350	35	3	126	6.25	2.0	14	11	14	6	12	9	12	6	12	5	10	1	10	4	N.	Brisk.
	9 "	.....	.....	.....	.....	.....	.....	6.0	2.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	10:30 "	.....	.....	.....	.....	.....	.....	6.0	2.0	14	8	12	9	12	9	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3 P. M.	.....	.....	.....	.....	.....	.....	6.0	2.0	14	8	12	6	12	6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
6	8 A. M.	88.9	54°	1 350	35	3	128	6.0	2.0	14	5	14	8	14	8	12	6	12	5	12	5	10	4	E.	Brisk.
	9 "	.....	.....	.....	.....	.....	.....	5.75	2.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	10:30 "	.....	.....	.....	.....	.....	.....	5.75	2.0	14	3	14	5	12	8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	11:30 "	.....	.....	.....	.....	.....	.....	6.0	2.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	1 P. M.	.....	.....	.....	.....	.....	.....	6.0	2.0	14	5	14	2	12	5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
7	8 A. M.	88.9	54°	1 500	35	3	130	6.0	2.0	16	3	14	8	14	8	14	6	12	0	12	6	10	6	S. W.	Brisk.
	9:30 "	.....	.....	.....	.....	.....	.....	6.0	2.25	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	1 P. M.	.....	.....	.....	.....	.....	.....	6.25	2.25	14	2	14	1	14	7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
8	8 A. M.	88.7	55°	1 350	40	3	125	6.25	2.25	14	4	14	5	12	3	12	3	12	2	10	2	10	4	W.	Brisk.

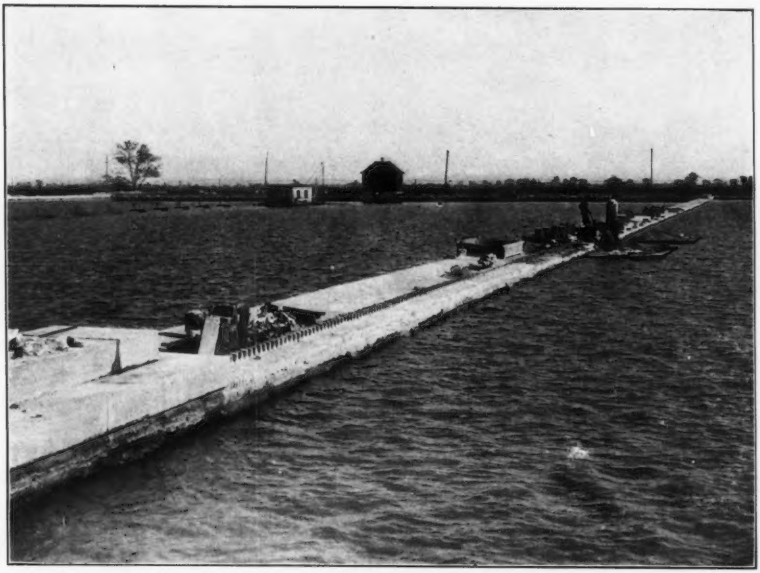


FIG. 1.—WEIR CONSTRUCTION.



FIG. 2.—WATER ENTERING BASIN, SHOWING LINE OF DEMARCATION BETWEEN CLEAR AND MUDDY WATER.

When the process was put into operation, however, defects and new problems presented themselves in rapid succession and it soon became evident that a design for a permanent plant would have to await the solution of some of these problems. After three years of study and experiment, plans and specifications have been prepared for a fire-proof building, equipped with crushers, conveyors, elevators, feeders, mixing-tanks, etc. The contract for this building was let on June 11th, 1907, for the sum of $89 500, to be completed by January 1st, 1908. Plans, elevations and sections are shown on accompanying plates.

The building will contain eight circular bins, of 20 ft. inside diameter and 40 ft. high, for the storage of sulphate of iron and lime. These bins will have a capacity of 10 600 cu. ft. each, providing for the storage of about 160 days' supply of sulphate of iron and about 45 days' supply of lime, at the present rate of use.

The lime bins will be practically air-tight to prevent deterioration while in storage. In April, 1906, a small bin, 6 by 6 by 6 ft. interior dimensions, was built of wood with double walls, the space between filled with pitch to one-half the height, the upper half being lined with tar paper covered with pitch. This bin was filled with lime, and sealed. A careful watch was kept for signs of heating, but up to June 1st, 1907, no evidence of deterioration had been found. In August, 1906, another bin of the same size was built of concrete 6 in. thick, and filled with lime. No damage has occurred to the lime in this bin after ten months' storage. Both these bins have stood exposed to the weather, without any protection, ever since they were built.

The bins in the new building will be constructed of reinforced concrete, faced on the outside with brick. Sections showing the reinforcement are shown on Plate LXXVI. The central part of the building will be of brick, and divided into three floors, *viz.*, the basement floor where the crushers and a portion of the conveying machinery are installed; the pump floor, containing the heater tanks and pumps; and the mixing floor where the mixing tanks and daily supply hoppers with all their appurtenances are located. The motive power for crushers, conveyors, elevators, mixers, etc., will be electricity on a 500-volt circuit. All motors will be of the latest type, having commutating poles, and will be operated from one switchboard.

The daily supply hoppers will have a capacity of 900 cu. ft. and will be supported on four pairs of helical springs as shown on Plate

LXXVII. Each spring will carry a safe load of 10 000 lb., and deflect ½ in. under a load of 1 250 lb. The purpose of having this hopper move vertically is for automatic control of the conveyors feeding the hoppers. When the hopper is full, it will stand at its lowest elevation, but as the contents are withdrawn the hopper will rise, and, on reaching a certain point, will automatically switch in the current driving the motors which operate the feeding conveyors. As the hopper becomes filled again, it descends and again cuts off the current, stopping the feeding conveyors.

The lime is fed from its daily supply hopper into automatic scales, each of which dump the required amount into its tank, at regular intervals, varying from 1 to 4 minutes. The scales are designed to weigh any amount from 30 to 120 lb. at a single load, the frequency of dumping also being adjustable between intervals of 1 and 4 min., the two adjustments giving quantities varying at the rate of from 10 to 80 lb. per minute.

The sulphate of iron is delivered from its daily supply hopper into the solution tanks by the feeders previously described.

The milk of lime flows from the mixing tanks into one of the heating tanks on the pump-room floor and thence to the collecting tank from which it is taken by the pumps. The collecting tank is supplied with a varying quantity of cold water, controlled by a float valve, for the purpose of cooling and diluting the milk of lime, and also for increasing the volume of dilute milk of lime, so that the pumps shall not empty the tank at any time because of the varying quantity of milk of lime flowing from the mixing tanks, or because of the variable speed of the pumps themselves on account of variation in voltage of the current supplied.

The conveyors and elevators are shown in plan and elevation on Plates LXXVIII and LXXIX, and Fig. 3. The lump lime is unloaded from the car into the crushers, A and B, on the east side of the building. It is crushed to ½ in. and smaller, and carried by Conveyors A and B to Conveyor C, which dumps it into the boot of Elevator D, by which it is elevated to Conveyor E, which runs above the lime storage bins and dumps into these bins through doors provided for that purpose.

In taking lime from the bins for daily use, the crushed lime feeds by gravity into Conveyor F, which delivers it to Elevator G, which,

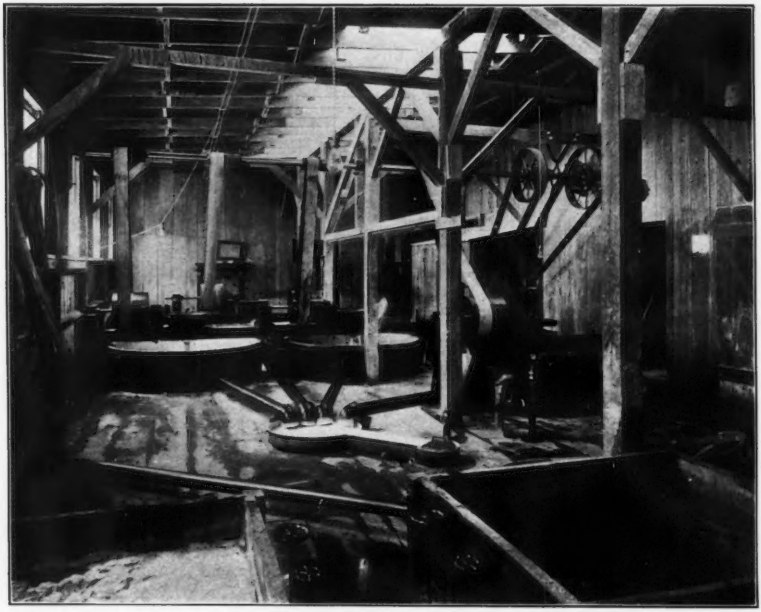


FIG. 1.—INTERIOR OF COAGULANT HOUSE, JUNE 13TH, 1905.

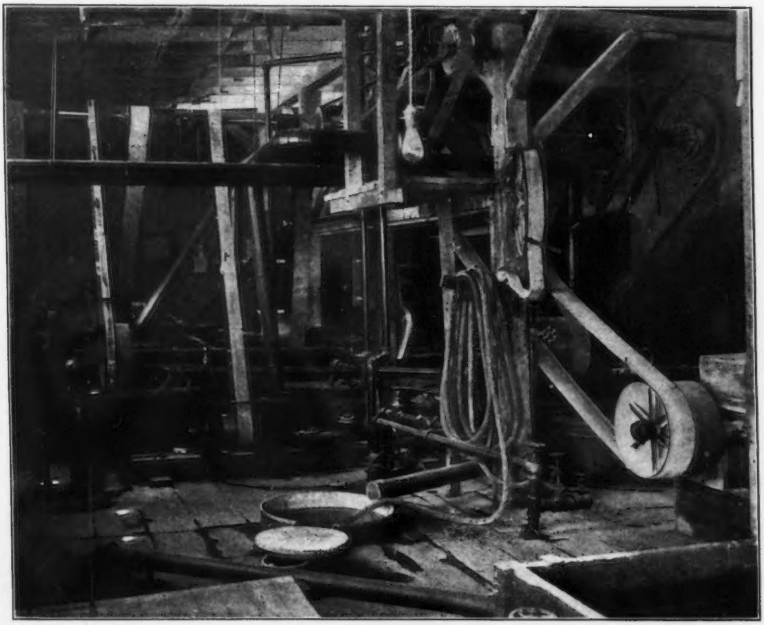


FIG. 2.—INTERIOR OF COAGULANT HOUSE, APRIL 9TH, 1907.

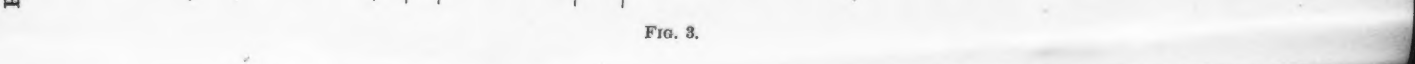


FIG. 3.

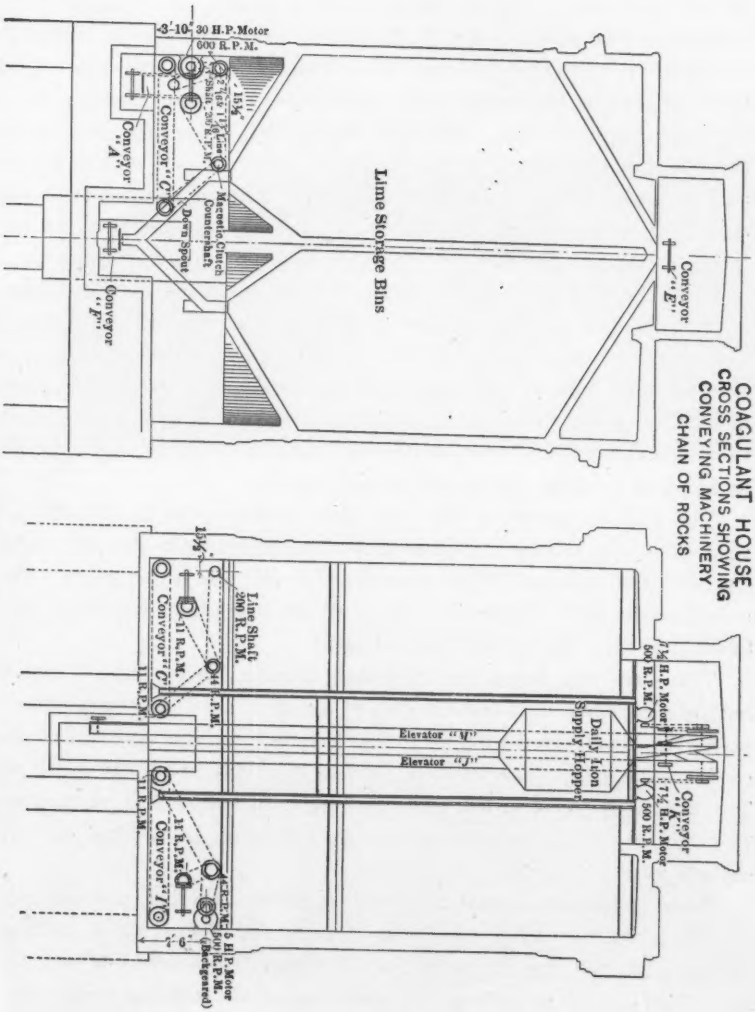

COAGULANT HOUSE
CROSS SECTIONS SHOWING
CONVEYING MACHINERY
CHAIN OF ROCKS
Lime Storage Bins
Conveyor "A"
Conveyor "B"
Conveyor "C"
Conveyor "D"
Conveyor "E"
Conveyor "F"
Conveyor "G"
30 H.P. Motor
600 R.P.M.
Magnetic Clutch
Countershaft
Down Spout
Lime Shaft
200 R.P.M.
Elevator "H"
Elevator "I"
Daily Ration
Supply Hopper
7½ H.P. Motor
600 R.P.M.
11 R.P.M.
5 H.P. Motor
500 R.P.M.
(Backgeared)

Fig. 3.

in turn, carries it up to the lantern and delivers it to the daily supply hopper.

The sulphate of iron will be unloaded from cars on the west side of the building by an automatic power shovel into Conveyor H, whence by Conveyors H and I, Elevator J and Conveyor K, it will be delivered into the storage bins. It will be taken from the bins by the same method as the crushed lime, by Conveyor L and Elevator M, to the daily supply hopper. As before mentioned, the motors driving the conveyors and elevators feeding the daily supply hoppers will be started and stopped automatically by the vertical motion of the hoppers. The daily supply hoppers will each carry from 50 000 to 60 000 lb. of material, which is sufficient for from 2 to 2½ days' supply of sulphate of iron, and from 16 to 20 hours' supply of lime, at the present rate of use.

In case any of the machinery feeding the daily supply hoppers breaks down, provision is made for drawing either sulphate of iron or lime, or both, from the bottoms of the bins into small cars on the basement floor, from which they will be elevated by the freight elevator, shown on Plate LXXX, to the mixing floor, when the tanks will be fed by hand, as is being done at the present time.

The cost of operating the new plant is estimated at $17 000 per year, including interest and depreciation, as compared to $21 500, which has been the average cost of operation for the past three years. The actual yearly cost of operation alone of the new plant will be at least $9 000 less than that of the original plant.

There are now being built two new settling basins, Nos. 7 and 8, having a capacity of 75 000 000 gal., at a cost of about $500 000. These basins are constructed with reinforced concrete walls of sections shown on Plate LXXXI. The walls are backed with clay puddle 18 in. thick. The floor is covered with 9 in. of concrete, in blocks 8 ft. square, on 18 in. of clay puddle, the joints between the blocks being filled with an asphalt filler.

These basins are located as shown on Plate LXXXII, and are connected to the drawing conduit, the by-pass, and Basin No. 6, in such manner that the flow of water may be changed according to any desired direction, thus making the operation of the settling basins perfectly flexible and adaptable to any conditions which may arise. Basin No. 8 is connected with the filling chamber by a 7-ft. steel-pipe con-



FIG. 1.—PRESENT COAGULANT HOUSE.

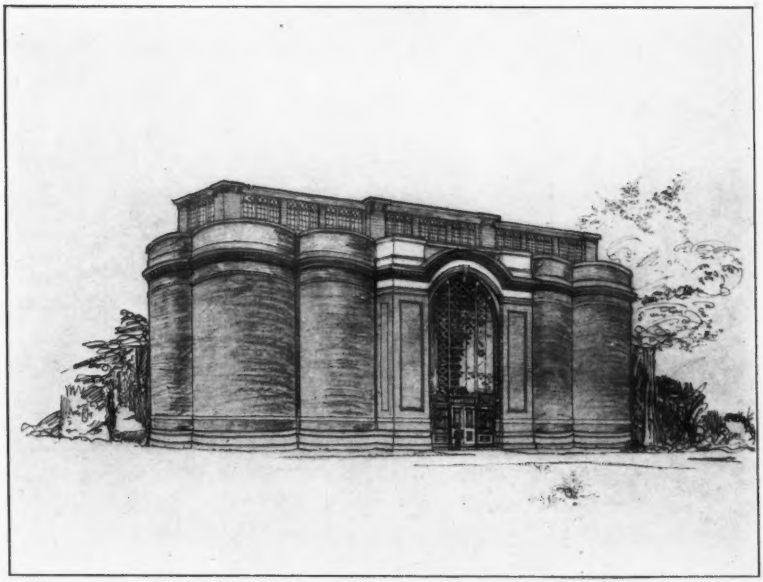


FIG. 2.—NEW COAGULANT PLANT.

nection, so that the raw water may be introduced directly into it, making it a primary settling basin if desired, and when Basin No. 6 is made the primary settling basin, clear water may be drawn from Basin No. 1 through the 7-ft. pipe into Basin No. 8, thus making Basin No. 7 the final basin from which the treated water is drawn. With these basins in service and the improved facilities for uniform treatment afforded by the new coagulating plant, there is no reason to doubt that St. Louis will be supplied with water as agreeable to the eye and as pure and wholesome as is enjoyed by any city in the United States.

From the inception of the first idea of the St. Louis process of clarifying and purifying the water supply, the work has been prosecuted with all the energy and skill of the Department, individually and collectively. No one man, apart from the Water Commissioner himself, who, of course, has borne the greatest portion of the responsibility of success or failure, can be considered to be entitled to more credit for its success than any other employee engaged upon that particular work. It would not be just to conclude this article without mentioning the valuable and efficient services of Mr. Arthur I. Jacobs, Engineer in Charge of the Supply and Purifying Division, and Mr. Wilson D. Monfort, Chemist of the Department, both of whom have contributed largely to the success of the process.

Vol. XXXIII. SEPTEMBER, 1907. No. 7.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

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GAS ENGINES.

An Informal Discussion at the Annual Convention, July 10th, 1907.*

SUBJECT FOR DISCUSSION:

"(*a*) What is the best apparatus and most economical system for cleaning producer or furnace gas, to be used in gas engines?

"(*b*) To what extent is ordinary producer gas, made from bituminous coal, used in gas engines, and what practical results have been obtained by any methods for removing tar or soot?"

BY TIMOLEON GEELEN, ESQ.

Mr. Geelen.

TIMOLEON GEELEN, ESQ. (by letter).—The following discussion relates principally to the development of gas generators in Europe.

Besides illuminating gas, which is too costly for heating purposes, two other kinds of gas have been in use in Europe for a long time, namely, Siemens gas, and water gas.

Siemens gas is produced by the incomplete burning of cheap coal in a high furnace, and consists principally of carbon oxide and nitrogen.

1 kg. of carbon, by combustion into carbon oxide (CO), produces 2 400 t. u. (4 320 B. t. u. per lb.).

1 kg. of carbon, by combustion into carbonic acid (CO_2), produces 8 000 t. u. (14 400 B. t. u. per lb.).

The highest possible efficiency practically obtainable, therefore, is $\frac{8\,000 - 2\,400}{8\,000} = 0.7$.

* Continued from August, 1907, *Proceedings*.

Mr. Geelen.

As the temperature of the Siemens furnace is very high, the gas is not exactly suitable for power purposes, as it needs to be cooled, and therefore the efficiency of the generator is small. Water gas seems to be more suitable. It is produced by passing steam through burning coal, and consists principally of carbon oxide and hydrogen.

$$C + H_2O = CO + 2H.$$

12 kg. of carbon require for their combustion 16 kg. of oxygen or 18 kg. of water, thus corresponding to 1 kg. of carbon to 1.5 kg. of water.

1 kg. of carbon, by combustion into CO, produces 2 400 t. u. (4 320 B. t. u. per lb.).

1.5 kg. of water requires by decomposition $1.5 \times 3\,200 = 4\,800$ t. u. ($1.5 \times 5\,760 = 8\,640$ B. t. u. per 1.5 lb.).

This shows that a water-gas furnace does not produce heat, but, on the contrary, consumes heat. For this reason, such a furnace cannot work continuously, but must be blast warm after having cooled itself. For a regular service, at least two furnaces are necessary, and these have to work alternately. The reversion, which is necessary every few minutes, makes the service very incommodious.

Water gas consists of equal parts of carbon oxide and hydrogen. The molecular volume of each of the two kinds of gas is 23.13. The formation heat of water is 58 100 t. u., of carbon oxide, 29 000 t. u., and of carbonic acid, 96 960 t. u. The heating value of the pure water gas, therefore, will be:

$(58\,100 + 96\,960 - 29\,000) \div (2 \times 23.13) = 2\,730$ t. u. per cu. m. (306 B. t. u. per cu. ft.).

The reaction in the Siemens furnace is: $C + O = CO$. As this furnace does not receive oxygen, but atmospheric air, a quantity of nitrogen also enters the process, namely:

$$\frac{0.787}{0.213} \times \frac{1}{2} \times 23.13 = 42.71 \text{ cu. m.}$$

The calorific value of the gas, therefore, is:

$(96\,960 - 29\,000) \div (23.13 + 42.71) = 1\,030$ t. u. per cu. m. (115 B. t. u. per cu. ft.).

It seemed advisable, therefore, to make a combination of the two processes, and introduce a mixture of air and steam in the furnace. The necessary heat for making the water gas is then furnished by the formation of the Siemens gas, and therefore the furnace can work continuously, the reaction being:

$$C + O = CO; \quad C + H_2O = CO + 2H.$$

In addition to 23.13 cu. m. of hydrogen and 46.26 cu. m. of carbon oxide, the gas will also contain 42.71 cu. m. of nitrogen, as already mentioned; therefore, the 112.1 cu. m. of gas will contain

Mr. Geelen. 41% of carbon oxide, 21% of hydrogen and 38% of nitrogen. Its calorific value will be:

$[58\,100 + 2\ (96\,960 - 29\,000)] \div 112.1 = 1\,700$ t. u. per cu. m. (190 B. t. u. per cu. ft.).

The Englishman, Dowson, was the first to introduce an arrangement to produce such mixed gas, about 1885. At first he used anthracite as fuel, which gave him a pure gas; later, he also used coke. Fig. 4 shows the general arrangement. The water is evaporated in the boiler, *A*. The superheated steam passes through the suction air blast, *a*, and the mixture of air and steam passes under the grate. The gas produced in the generator, *B*, passes the cleaner, *C*, then through the scrubber, *E*, and the saw-dust cleaner, *D*. The gas then passes into the receiver.

DOWSON'S GAS PRODUCER

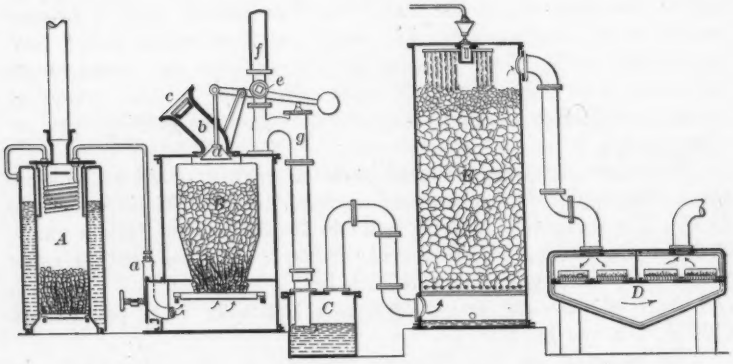


FIG. 4.

An attempt has been made to use the Dowson system by utilizing the heat of the gas which leaves the generator, and in this way an efficiency of 75% has been obtained. This means that the calorific value of the gas is equal to three-fourths of that of the carbon from which it has been produced.

The most important simplification in the construction of gas generators is that of Bénier, dating from about 1895. Instead of introducing the air by a steam blast, as in Dowson's arrangement, Bénier leaves the function of introducing the air to the engine itself, establishing in this way the well-known suction-gas arrangement. Fig. 5 shows the general arrangement of such an installation.

The evaporator forms a part of the generator, and the water is heated to a temperature of from 80 to 90° cent. by the passing gas.

This evaporator is in communication with the atmospheric air through an opening, *e*. The entering air strikes the surface of the heated water and, after being saturated with water vapor, passes under the grate. The evaporator is provided with an overflow conducting the water into the ash-pit where it extinguishes the ash and also partly evaporates, thus contributing to the formation of gas. Mr. Geelen.

A further change in the general construction of gas generators was made by Taylor, who separated the evaporator from the generator, resulting in the arrangement shown in Fig. 6.

Gas generators have also been constructed without the evaporator, the water being injected in small quantities which evaporate immediately. The advantage of this combination is that it is not

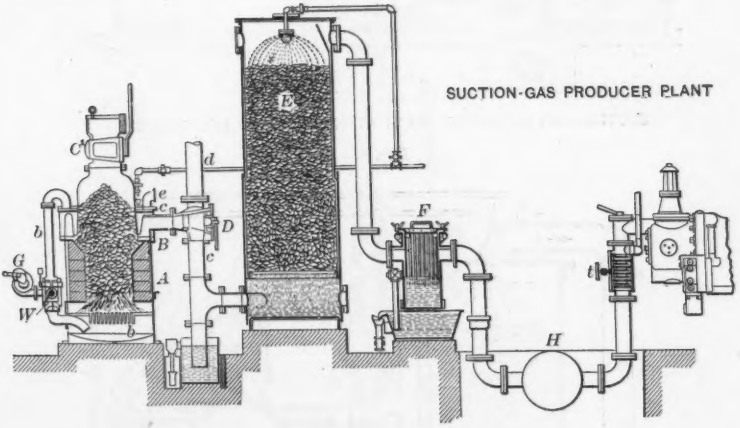


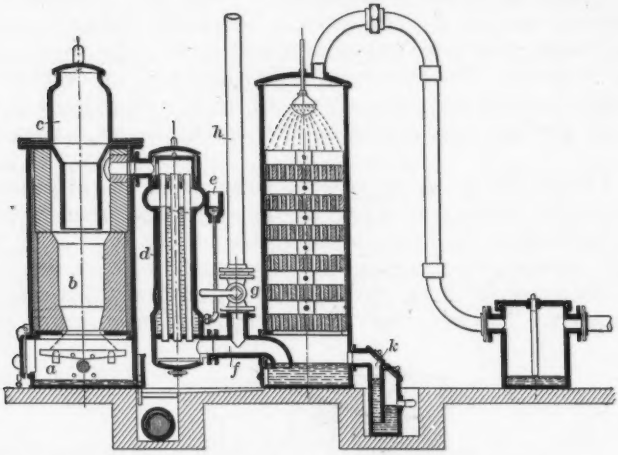
FIG. 5.

necessary to wait until the water in the evaporator has reached the required temperature before the machinery can be put into operation. Fig. 7 shows a generator of this kind.

The air enters the hollow cover of the generator at *a*, where it is heated, and then passes into the space, *b*, where it is heated still more by the gas. Into this space the water is injected and evaporates immediately, the mixture of air and water vapor being conducted under the grate through the pipe, *d*.

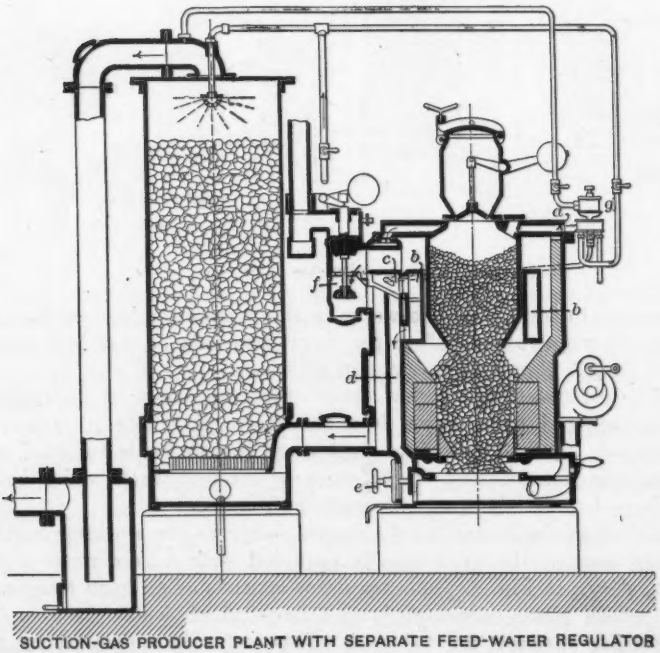
To adapt the quantity of injected water to the working suction of the engine, the generator is provided with a feed-water regulator, shown in Fig. 8. This regulator consists of an open receptacle into which water enters at *h*, and from which water flows to the evaporator through the valve, *i*. This valve is supported by the

Mr. Geelen.



SUCTION-GAS PRODUCER PLANT WITH SEPARATE EVAPORATOR

FIG. 6.



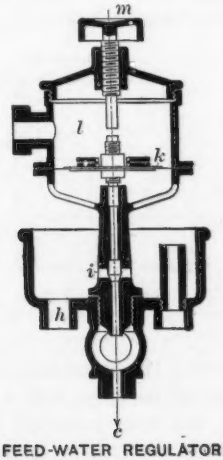
SUCTION-GAS PRODUCER PLANT WITH SEPARATE FEED-WATER REGULATOR

FIG. 7.

flexible plate, *k*, which is the bottom of the box, *l*. The lift of this plate is limited by the screw, *m*. The box, *l*, is connected with the suction pipe of the engine. The stronger the suction, the higher the plate, *k*, will be lifted, and the more water will flow to the evaporator through the valve, *i*. Mr. Geelen.

After leaving the generator the gas requires cleaning, and this is generally done in the different apparatus described hereafter.

At first the gas passes a receptacle filled with water, where it loses a portion of the dust it contains. Afterward it passes an apparatus generally called a scrubber. This is a high cylindrical receptacle filled with coke, the gas entering through an opening near the bottom. In passing upward it meets a spray of water



FEED-WATER REGULATOR

FIG. 8.

which cools it. In this apparatus the gas loses also a large portion of the tar it contains.

Another apparatus for cleaning the gas is the so-called condenser. It consists of a number of perforated plates placed in such a way that the gas passing through a hole of one plate strikes the unperforated part of the next plate, thereby losing a portion of the tar it contains.

If the fuel used contains much tar, the gas is forced to pass another cleaner, where it is purified on its way through a bed of saw-dust.

The installations which have been mentioned are only limited to the use of anthracite, coke or charcoal, having a consumption

Mr. Geelen. of from 400 to 600 g. per h.p. per hour, according to the quality of the fuel.

Fuel containing much tar, and also other cheap bituminous coal, cannot be used continuously with good results in these generators, and therefore constructors have been endeavoring to discover other arrangements better adapted to the use of such fuels.

The first to succeed in installing a large plant of this kind was Dr. Mond, in England. To avoid the baking of the fuel and the formation of clinkers, he introduced large quantities of steam into the generator, and burned the heavy tar-containing gas by forcing it to pass the hot fuel bed of the generator. The whole arrangement has a large calorific loss, and can only be executed on a large scale, because it cannot be worked with profit unless it is combined with an installation for the production of ammonia sulphate, the whole system being thus very complicated. Notwith-

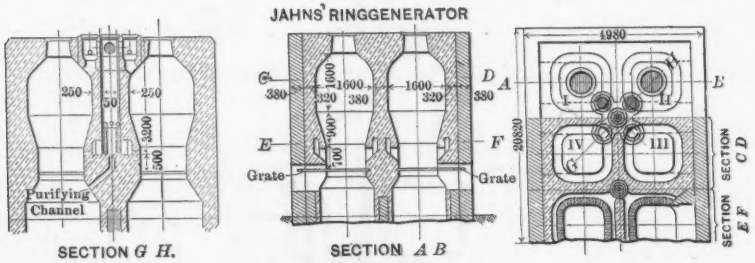


FIG. 9.

standing this inconvenience, the installation has given satisfactory results during ten years of service, and a new 12 000-h.p. plant, working with Mond gas, has been installed recently in Madrid.

Quite a different system has given satisfactory results in Germany. This arrangement, called Jahn's ring generator, is working with the poorest coal, even with the so-called "Klaubeberge."

As seen from Fig. 9, Jahn's ring generator is composed of four generators working in one group. They are taken into service one after the other, and the gas of the third and fourth is led through the first and second, which are already burning well. In these generators is found a real formation of gas, and, besides this, the combustion and decomposition of the heavy tar-containing gas. When the fuel-contents of the first generator of the group, which has been longest in service, are no longer sufficient to aid in the process, this generator is put out of service, after being entirely exhausted. It is then cleaned and recharged, and is again connected to the other generators, the other three advancing correspondingly in the process.

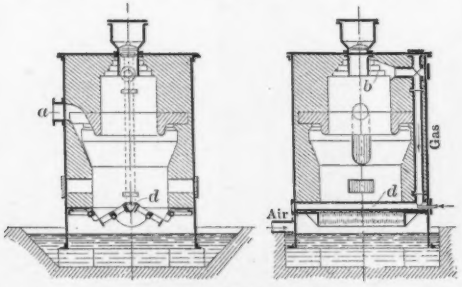
Mr. Geelen.

It must be stated, however, that this system, also, is only possible for large installations.

The modern construction of nearly all generators for the use of bituminous coal, lignite or turf, is based on the same principle, that of changing the fuel first into coke, and afterward gasifying this coke. The gas formed by the coking of the fuel contains much tar; this is decomposed, and the gas is made "permanent" by passing it through a bed of incandescent fuel in the generator.

The fuel column in these generators is made high, and the gas when produced leaves the generator in the middle of the column. The fuel in the upper part of the generator is coked, and the gas thus formed is led under the grate, being forced to pass the hot fuel bed of the generator, where it is made permanent. There is no loss in this process, as the carbonic acid and the water formed by the combustion are again reduced to carbon oxide, hydrogen, and oxygen.

Fig. 10 shows the details of a generator of this kind.



DANIELS' GENERATOR
FIG. 10.

The gas is sucked off at *a;* the distillation gas produced in the upper part of the generator, *b,* falls through the pipe, *i,* into the pipe, *d,* the latter ending in the middle of the grate. Into this pipe steam is also introduced. The distillation gas is thus forced to pass the fire, and is made permanent.

A different arrangement to obtain the same effect is made by the construction of the so-called "double-working generators." They have two burning zones, one on the grate below, the other at the top of the fuel column, while the gas is sucked off in the middle of the column.

The fuel at the top of the column is at first coked, then passes into the upper burning zone, is extinguished on its way downward, and is finally consumed over the grate. The distillation gas formed in the upper part is sucked through the upper burning zone and is thereby made permanent.

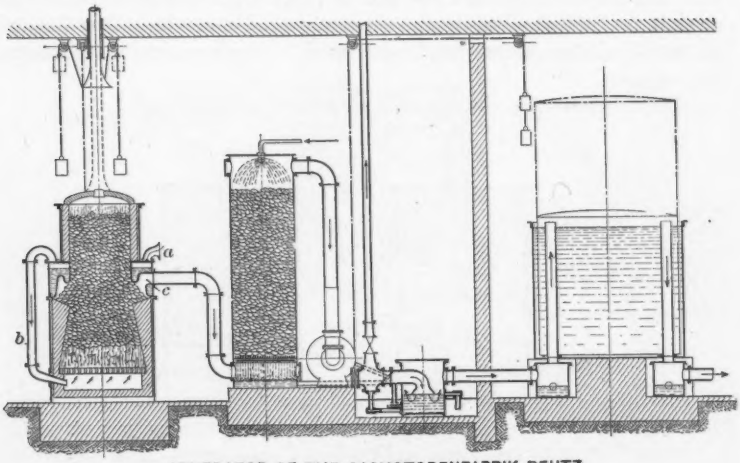
Mr. Geelen.

Fig. 11 shows a type of these generators.

It seems, however, that these generators also have not given entirely satisfactory results where coking coal is used, and it has been necessary to use efficient mechanical arrangements in their upper parts to prevent this baking.

One kind of bituminous coal has proved excellent for use in the double-working generators, this fuel being lignite.

Lignite is obtainable almost everywhere at a very low price. In 1902 the Gasmotorenfabrik Deutz, Germany, constructors of the Otto engines, had installed at the Düsseldorf Exhibition a suction-gas plant which worked with lignite. This installation is still in operation, and is giving entirely satisfactory results.



GENERATOR OF THE GASMOTORENFABRIK DEUTZ

Fig. 11.

In general, the suction-gas process, with lignite as fuel, is very simple. Lignite does not bake together, and the tar in the gas is not of as much importance as the tar in the gas from ordinary coal. The only inconvenience is the bad quality of the water leaving the cleaning apparatus.

In Germany lignite briquettes are used to a great extent, and have given excellent results. While the common lignite has from 40 to 60% of water and a calorific value of from 2 000 to 3 800 t. u. (from 3 600 to 6 840 B. t. u. per lb.), the lignite briquettes have less than 20% of water and a calorific value of about 4 500 t. u. (8 640 B. t. u. per lb.).

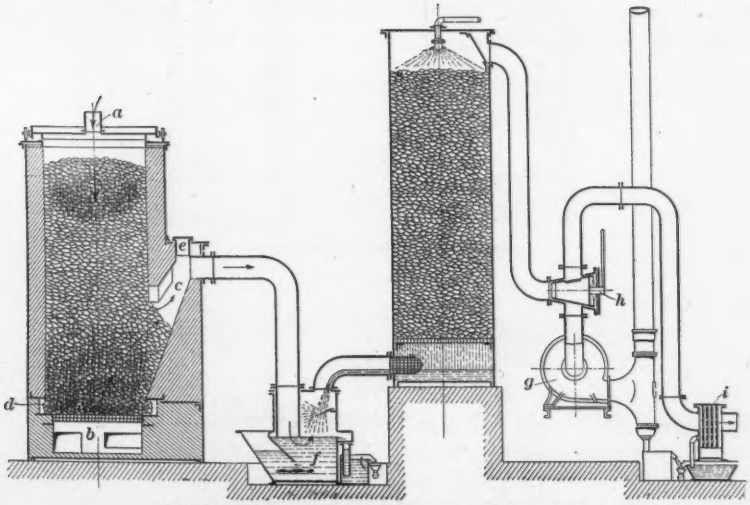
Fig. 12 is an illustration of a lignite generator.

Turf, also, can be used in the double-working generator; and even poor classes of turf, with from 40 to 50% of water, can be used

advantageously. Turf gives from 1.3 to 1.8 cu. m. of gas per kg. (from 21 to 29 cu. ft. per lb.), corresponding to an average calorific value of from 1 350 to 1 499 t. u. per cu. m. (from 2 400 to 2 500 B. t. u. per cu. ft.). Mr. Geelen.

Fig. 13 represents a generator for the use of turf.

The shaft consists of two parts, the upper and wider part being provided with two grates, and the lower and narrower part with the ordinary grate. During the service the turf burns only at the border of the upper grate. The inner part of the fuel column does not burn but sinks gradually downward, thereby being coked. The gas produced in the upper part of the generator passes through the hole, *c*, and the pipe, *d*, under the grate; then it goes through the burning zone, and is sucked off through the hole, *c*.



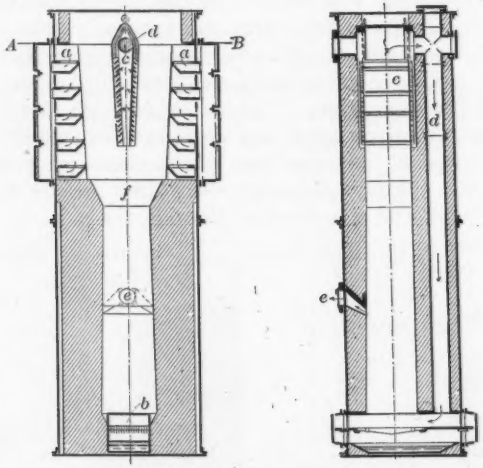
GENERATOR OF THE GASMOTORENFABRIK DEUTZ

Fig. 12.

Another generator may be mentioned, namely, that of Riché, which is especially adapted for the gasification of wood. It must be stated, however, that wood alone does not give good results in service, and that a second fuel, carbon, is necessary to aid in the process. Fig. 14 shows the general arrangement of this generator.

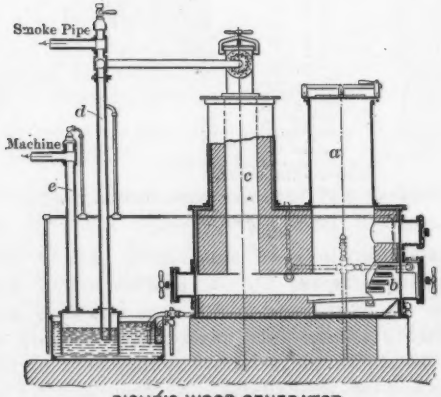
It is composed of two shafts, the first serving as a feeding reservoir for the grate, *b*, on which the wood is burning, the second being filled with charcoal for the reduction of the produced carbonic acid. The tar-containing gas passes the fire, over the grate, and is thus burned and reduced to carbon oxide by the burning charcoal. The gas is then cooled in the pipes, *d* and *e*, by injected water.

Mr. Geelen. The idea of using two different kinds of fuel is also brought out in the generator of Lencauchez. However, instead of using two different generators, he uses only one for both kinds of fuel, as shown in Fig. 15.



KOERTING'S TURF-GENERATOR

FIG. 13.



RICHÉ'S WOOD-GENERATOR

FIG. 14.

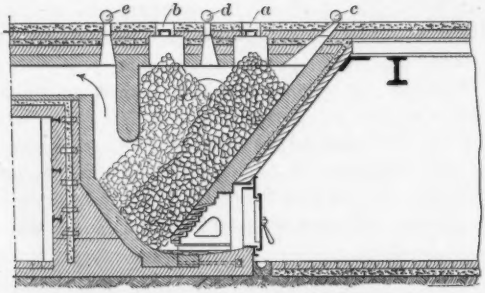
Gas coal is introduced into the generator through the hole, *a*, coke is introduced through the hole, *b*. The water is evaporated in the ash-pit. The gas produced is forced to pass the burning bed of coke, thus being reduced. The holes, *d* and *c*, will give black

smoke, while the hole, *c*, is giving colorless gas. This generator is especially designed for heating purposes. From 75 to 80% of gas coal requires from 25 to 20% of coke. Mr. Geelen

The arrangements for cleaning the gas produced in the generators described are the same as those already mentioned in connection with the anthracite and coke generators.

It is not the writer's intention to give a full description of the great number of gas generators on the market. Nearly all these are based more or less on the principle already mentioned, namely, that of changing the fuel first into coke, which is then gasified, the tar-containing gas being forced to pass an incandescent bed of fuel, where it is made permanent.

The coke furnaces and high furnaces are generators of quite a different class. In Germany there are two different classes of coke furnaces. The first is the so-called "Flammöfen," which are heated



LENCAUCHEZ' GENERATOR

FIG. 15.

with all the gas the furnace produces. The heat of the burned gas, which has a temperature of 1 100° cent., is used everywhere for heating boilers. The result obtained therewith is, that for every kilogram of coal put into the furnace 1.2 kg. of water can be evaporated, thus regaining about one-sixth of the heat of the coal.

The second class of coke furnaces contains the so-called "Nebengewinnungsöfen," which deliver not only the hot burned gas but also coke gas. The gas leaving the coke furnace is first cooled, then it is separated from the tar, ammonia, benzol, etc., which it contains, and is then returned partially to the furnaces, where it heats them, the heat of the burned gas being utilized under steam boilers. The remaining gas could be utilized in gas engines, but it is also generally used to heat steam boilers. The quantity of this gas depends mainly on the quality of the fuel, and especially on the water it contains.

The combined heat of the burned gas and the coke gas of the "Nebengewinnungsöfen" does not evaporate as much water as the

Mr. Geelen.

heat of the burned gas of the "Flammöfen" alone, being only from 0.8 to 0.9 kg. of water per kg. of coal. Two-thirds of this belongs to the burned gas, and one-third to the remaining coke gas.

If it is intended to dispose of the largest possible quantity of coke gas for use in gas engines, and thus not use the heat of the burned gas for heating steam boilers, the coke gas leaving the furnace is led into the so-called "Regeneratif" furnace. The quantity of gas which can be disposed of by using this furnace is from 100 to 140 cu. m. per ton of coal.

It is now a question of great interest to know how the highest possible horse-power can be obtained from the disposable heat. Experience has shown that nearly the same capacity is obtained in the three following cases:

1.—By utilizing the entire heat of the burned gas of the "Flammöfen" in modern steam boiler plants;

2.—By utilizing the heat of the burned gas of the "Nebengewinnungsöfen" in steam engines or turbines, and the remaining gas in gas engines;

3.—By utilizing the whole amount of gas of the regenerator furnace in gas engines.

At first sight it seems to be strange that, using a regenerator furnace and gas engines, it is not possible to produce a larger capacity. But the fact that a large amount of heat is lost through the chimney of the regenerator furnace has to be taken into consideration.

If only the "Nebengewinnungsöfen" are considered, about one-third more capacity can be obtained by installing a combined steam and gas plant, than by installing a whole steam plant; but the service is somewhat difficult with such a combined system, and will only give satisfactory results in large plants.

For this reason it must not be thought strange that, for instance in Germany, gas engines working with coke-furnace gas are not yet used to any great extent. If other arrangements are successful in obtaining more disposable gas from the regenerator furnaces, the coke gas engine will make its way as rapidly as the high-furnace gas engine.

In the high furnace the conditions are much more favorable, as it delivers considerable quantities of gas. However, in composition, coke-furnace gas and high-furnace gas are quite different. Coke-furnace gas, produced by the gasification of coal, contains principally methane (CH_4) and hydrogen, and has a very high calorific value of about 4 000 t. u. per cu. m. (448 B. t. u. per cu. ft.).

High-furnace gas, on the contrary, is a poor gas, and contains only one-third of combustible substances, especially carbon oxide

(CO), and has a calorific value of only from 800 to 900 t. u. per cu. m. (from 90 to 100 B. t. u. per cu. ft.). Mr. Geelen.

High-furnace gas requires but little air in its combustion, about its own volume; coke-furnace gas requires from 5 to 6 times more air, and, notwithstanding this, the mixture is about 20% stronger than the high-furnace gas mixture, so that coke-gas engines could be built smaller than high-furnace gas engines. This is principally due to the hydrogen contents in coke-furnace gas.

Generally, however, the dimensions of each kind of machinery are made the same, taking into consideration an average indicated pressure of 4.8 atmospheres (about 70 lb.). The only difference in their construction is that the compression in the cylinder is different for the two kinds of gas, being for high-furnace gas at least 12 atmospheres (about 185 lb.), and for coke-furnace gas only 8 atmospheres (about 115 lb.).

The cleaning of these gases is of the greatest importance, and a distinction has to be made if the gas is to be used only for heating purposes or for gas-engine service. In the first case the dust contained in the gas may be about 0.5 g. per cu. m. (about 0.0003 lb. per cu. ft.), in the second case only a quantity of 0.02 g. per cu. m., or less, is admitted (about 0.0000013 lb. per cu. ft.).

However, as the better-cleaned gas has also given better results in steam-boiler plants, the same cleaning process is generally adopted at the present time for both cases of utilizing the gas.

The coke-furnace gas has its principal cleaning during the process of separating the tar, ammonia, benzol, etc., and has only to be cleaned of the remaining tar, sulphur and cyanide.

High-furnace gas has to be separated principally from the dust it contains.

The remaining tar in coke-furnace gas is separated by passing the gas through a coke-scrubber and afterward through a drying apparatus. Sulphur and cyanide are separated by passing the gas through an apparatus containing "Raseneisenerz," a carbonic iron ore. If the gas is not freed sufficiently from sulphur, it may soon be observed by the corrosion of the piston rod, valves, and other parts.

The separation of dust from high-furnace gas requires a considerable amount of force, being about 2% of the capacity of the working machinery. The general principle followed in this cleaning process is, to force the dust into the water, with which it is then removed.

An apparatus of this type, very much used in Germany, is the centrifugal cleaner of Theisen, the construction of which is shown in Fig. 16. Besides this, a number of centrifugal cleaners have been put on the market, also a certain type of ball mill.

Mr. Geclen. As already stated, the gas in these cleaning apparatus is freed from dust, so that it contains not more than 0.02 g. per cu. m. (0.0000013 lb. per cu. ft.). Therefore it contains less dust than the surrounding air in the working plant. As a final cleaner, a slack-wool, or a saw-dust, cleaner is used.

The great importance of the use of coke-furnace gas and high-furnace gas is seen clearly, if an approximate calculation is made in reference to the capacity of coke and high furnaces.

During 1906 the production of coke in Germany was about 20 000 000 tons, corresponding to about 27 000 000 tons of coal.

For calculating the capacity which can be obtained from the disposable heat, we accept, per horse power per hour, in modern

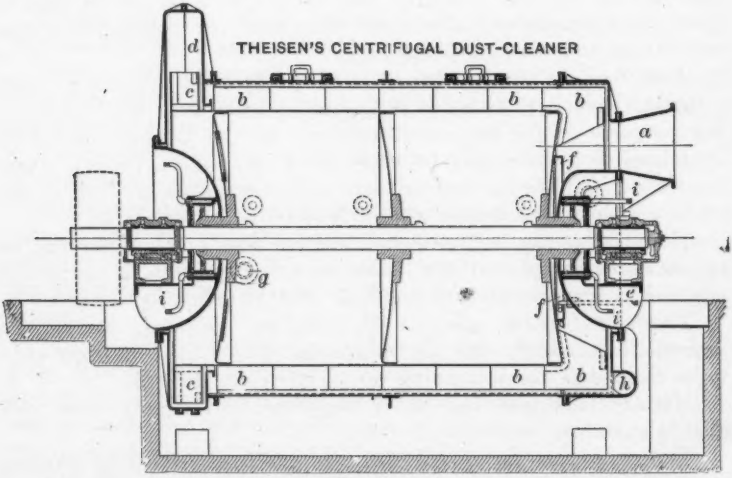


FIG. 16.

steam engines or turbines, 6 000 t. u. (about 1 500 B. t. u.) or 6 kg. (13.2 lb.) of superheated steam; and for modern gas engines, 3 000 t. u. (about 750 B. t. u.). In these figures all possible losses are included.

Taking this into consideration, we find for coke furnaces a disposable capacity of about 560 000 h.p. in combined steam engines and gas plants, or in pure gas plants.

Still more favorable conditions are found with high-furnace gas.

The iron production during 1906 in Germany was about 12 000 000 tons. Per ton of iron produced, 5 000 cu. m. of gas are produced (176 585 cu. ft.), with an average calorific value of about 800 t. u. per cu. m. (about 90 B. t. u. per cu. ft.). Of this quantity, 2 500 cu. m. are required to heat the air, thus leaving the remaining

2 500 cu. m. for use in gas engines. According to this, we find a disposal capacity of 1 000 000 h.p. in gas engines, or a capacity of 500 000 h.p. utilizing the gas in modern steam engines or turbines. Thus the total capacity which can be obtained in Germany alone by utilizing coke-furnace and high-furnace gas is about 1 500 000 h.p. Mr. Geelen.

In the United States, where the production of coke and iron is much greater than in Germany, still more surprising figures may be found.

Coke-furnace and high-furnace gas received only special attention after the successful construction of large gas engines of a practical type. The construction of these engines was begun about 1890, and the makers encountered many difficulties. Nearly all constructors took the small gas engine (and the good results obtained with it) as a model for the construction of the larger types, and it was especially the construction of the cylinder head which caused the greatest difficulty; but, after abandoning this method of construction, and taking into consideration the results obtained in building large steam engines, they succeeded at last in making large gas-engine units, which would work under complete guaranty.

It is not the writer's intention to describe the very interesting details of the construction of these large gas engines. He will only state here that the largest gas engines yet built have a maximum capacity of from 1 000 to 1 500 h.p. per cylinder, and that the total maximum capacity of engines built in tandem-compound arrangement has been 3 500 h.p.

Vol. XXXIII. SEPTEMBER, 1907. No. 7.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

THE EFFECTS OF THE SAN FRANCISCO EARTHQUAKE OF APRIL 18TH, 1906, ON ENGINEERING CONSTRUCTIONS.

Discussion.*

BY LANGDON PEARSE, JUN. AM. SOC. C. E.

Mr. Pearse.

LANGDON PEARSE, JUN. AM. SOC. C. E. (by letter).—The writer would like to obtain information relative to concrete exposed to the continued heat of a furnace, or to hot flue gases, as in a chimney. Such information would throw some light on the wearing qualities of concrete as a fire resister. In the design of a flue for the new Scioto River Pumping Station at Columbus, Ohio (under the direction of John H. Gregory, M. Am. Soc. C. E., Engineer-in-Charge), there came up the question of exposing a concrete face to flue gases. A search of the literature on the subject gave little information, and finally it was decided to build the flue of a special concrete, using brickbats instead of crushed limestone for ballast, the flue to be lined inside with one thickness of fire-brick, and covered outside with pressed brick to match the wall of the boiler-room. This flue was 4 by 12 ft. inside, and cared for Babcock and Wilcox boilers having a total capacity of about 1 200 h.p.

The writer would also like to point out the utility of reinforced concrete columns built up of structural shapes securely riveted together, the steel being calculated to carry all the dead load and the concrete all the live load. If suitable connections be devised to catch the floor and beam rods, the difficulty of filling the column with a mass of

Continued from August, 1907, *Proceedings*.

horizontal rods can be avoided. Such a detail was worked out for the new McGraw Building in New York City. Or steel columns, calculated to carry all the load, dead and live, with a concrete cover and filling for fire protection only, may be used. Generally, architects desire small columns, sometimes asking for dimensions which are impractical in reinforced concrete as commonly designed unless very high working stresses are allowed. Mr. Pearse.

The use of steel column framing permits the use of smaller columns, puts the metal in far better shape to resist flexure, and removes all danger of poor columns caused by pouring a deep column packed full of round rods.

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WATER SUPPLY.

An Informal Discussion at the Annual Convention, July 10th, 1907.*

SUBJECT FOR DISCUSSION:

"Is it better policy to purchase and control water-sheds, thereby preventing the pollution of impounding reservoir supplies, or to suffer a certain amount of pollution of such supplies, relying upon filtration to correct the effects thereof?"

BY MESSRS. WILLIAM J. BALDWIN, GARDINER S. WILLIAMS, J. T. NOBLE ANDERSON, WILLIAM B. FULLER, J. WALDO SMITH, AND PABLO SOLÍS AND OCTAVIO GUZMÁN.

Mr. Baldwin. WILLIAM J. BALDWIN, M. AM. SOC. C. E.—Some 25 or 30 years ago, small filters were recognized as propagating beds. The speaker would like to ask whether there is anything in this, and what engineers know about it?

Mr. Williams. GARDNER S. WILLIAMS, M. AM. SOC. C. E.—It may be proper to say a word in regard to the kinds of bacteria that are to be dealt with, particularly in view of the statement of one of the speakers, that owing to the absence of light the number of bacteria may be very decidedly reduced in passing through a water-works system. It is to be borne in mind that those bacteria which are most dangerous to the human organism thrive in the darkness, to most of them light is germicidal, so that the above-cited condition would fail almost entirely to reduce the forms of bacteria which are in any way dangerous to health.

The subject of railroad pollution is certainly a serious one, as it can readily be seen that closing the closets while traversing water-

* Continued from August, 1907, *Proceedings*.

sheds might, in time, entail closing them altogether, and it seems that the more rational method of dealing with the question is either to provide receivers upon the cars for the dejecta, or to install such systems of drainage along the railroads as will divert the contamination from the water-shed. Mr. Williams.

It may be quite safely stated that while there is no question that a great deal can be done to improve a water supply by eliminating the sources of evident pollution from the water-shed, yet no such system will ever be perfect. It will never be possible to remove all such sources, and while the elimination of as many of them as possible is to be advocated, a community is not thereby warranted in using a surface water subject to possible pollution, without filtration. On the other hand, the mere filtration of the water or the mere existence of a filter operated by anybody is not a reliable safeguard. Whether the filter be of the slow-sand, or of the so-called rapid or mechanical type, it needs very close attention, and unless that careful watchfulness accompanies the operation, one cannot depend upon it any more than upon the ownership of a water-shed. A filter is a very delicate machine, and it must be carefully and skilfully handled.

It can be quite definitely asserted that, for a properly operated filter, there is no such thing as its becoming a propagation bed. The mechanical filter which is not washed at proper intervals will, of course, permit of the passage of bacteria by becoming filled, since the sand bed in such a filter operates simply as a strainer, and when the strainer is filled the material washes out at the bottom. In a slow-sand filter, however, there is no record known to the speaker of the condition suggested, in the 70 years' experience with that type; and with a mechanical filter, properly attended, nothing of the sort has ever occurred.

J. T. Noble Anderson, M. Am. Soc. C. E.—The speaker wishes to call attention to a point in Mr. Fuller's discussion, which must be due to some misapprehension on his part. He says that the water-sheds of several cities, among which he mentions Manchester, England, have been acquired at a cheap price. The speaker was employed many years ago on the Manchester water scheme, and also on that of Belfast, Ireland, and knows that the prices paid at both places were not what would be called cheap; for example, much of the Manchester water-shed was acquired from the Fleming family, who asked $2 500 per acre for the land. The Manchester Corporation offered $100 per acre —the great difference is manifest—and it was purchased for from $400 to $500 per acre. Mr. Anderson.

In the case of the Belfast water-works the average price originally paid for the land was about 10 shillings per acre per annum, which was the rental price paid by the farmer. This, with some other items, made the net return of the land required by the Belfast Corporation about $5 per acre per annum. With the compensation paid to the

Mr. Anderson.

tenant and that paid to the landlord, the land cost the Belfast Water Board on an average of from $200 to $250 per acre.

There is another point which has come up in Australia, and which the speaker thinks has been generally overlooked by writers on hydraulic subjects, and that is, the use of the acquired water-sheds for re-foresting, especially in sub-tropical countries. The cutting down of forests interferes greatly with the rainfall, therefore it is not only important, in many countries, to protect the water-shed from impurity, but also to protect it from natural conditions, so that the rainfall of the range in which the water-shed is situated will not be impaired. By the judicious planting of these water-sheds that result is obtained, and the rainfall may be actually increased and a revenue earned. In the State of Victoria, the City of Melbourne has a water-shed roughly estimated at 100 sq. miles of forest, that will suffice to supply a population of 750 000, which it is expected will be reached within the next 8 or 10 years, and the Government has further reserved 250 000 acres all of which will be conserved ultimately and used by the Melbourne Water Commission. The point is an exceedingly important one on the subject in hand.

Mr. W. B. Fuller.

WILLIAM B. FULLER, M. AM. SOC. C. E.—The speaker believes that all upland water supplies should be filtered, even though filtration is put in merely as a safeguard. Where it is suspected or known that pollution exists on an upland water-shed, the proper course to pursue is, first, to put in a filter, and then, if further funds are available, to buy up and remove the polluted portions of the water-shed.

While it is true, as has often been said, that "innocence is better than repentance," it must be recognized at the outset that no upland water supply, about which there could be any question regarding the necessity of buying up any portion of its area, can be pure; and unless the entire area is inaccessible to Man and beast, we have the ever present possibility of outside contamination of even the purest supplies.

Some of these possible sources of pollution have been pointed out, notably the contamination possible from railway trains traversing the water-shed and the need of keeping the closets closed during such times.

Passing over the difficulties and inconveniences attending the carrying out of such orders and the dangers present, supposing negligent attention on the part of the railroad officials, there are other sources of pollution of an inhabited region still more difficult to regulate, as, for instance, during the repair, construction, or reconstruction of railroads and roads where large numbers of laborers pollute the adjacent fields, the construction of country estates, the pollution by campers, picnickers and other nomadic hordes, and many other possibilities.

It is true that large impounding reservoirs assist greatly in reduc-

ing the gross and accidental pollutions mentioned, but the standard of purity now demanded in many communities will not stop at one possible means of correction, but demands the best correction that engineering science can offer. To this end the best and safest guard against both accidental and permanent pollution is a properly designed and scientifically operated filter, the filtered water passing directly into covered conduits and not again exposed to the air, or possible contamination, until it reaches the tap of the consumer. Mr. W. B. Fuller.

In advocating filtration the speaker does not wish to be understood as considering it a sure specific for all water evils, and he certainly advocates, first, the securing of the purest water supply from the least polluted upland possible; and, second, the keeping of this upland supply as pure as possible before delivery to the filters. To this end, he is a firm believer in the necessity of draining all stagnant and marshy places; the removal, by purchase or otherwise, of undesirable persons and manufacturers from the water-shed; the organization and efficient maintenance of sanitary patrol; and the taking of all possible precautions against pollution. The less the filter has to do, the safer the water, but the filter should stand at the outpost and guard against enemies that slip in unawares, as well as against those that are known.

J. Waldo Smith, M. Am. Soc. C. E.—A large impounding reservoir at the lower limit of a water-shed is, from a sanitary point of view, one of the greatest safeguards which can be provided for a water supply. The sanitary quality of a water is undoubtedly increased by long periods of storage, though the storage may have but little effect on either its taste or appearance. In fact, the physical quality of a water may be made worse by storage, and for this reason as well as to satisfy the proper public demand for a water, clear, and pleasant to look at, filtration is necessary. Mr. J. W. Smith.

The question as to whether or not conditions in a storage reservoir can be improved by stripping its bottom and sides of most of the original organic matter is an important one. Recent studies indicate that the effect of stripping is to guarantee a somewhat better quality of water for a few years, but that, in the end, the conditions will be the same as though but little work in this direction had been done. An unstripped reservoir will improve; a stripped reservoir will grow worse until finally, if all other conditions are the same, the quality of water delivered by two such reservoirs will be identical. Even at its very best, stripping is not an absolute guaranty; vegetable growths may occur in any reservoir and can only be guarded against by thorough aeration followed by filtration.

Señores Pablo Solís and Octavio Guzmán* (by letter).—The writers congratulate themselves, as representatives of the State of Puebla, upon the opportunity that now presents itself of knowing, *Señores* Solís and Guzmán.

* Delegates to the Convention of the American Society of Civil Engineers from the State of Puebla, Mexico. (Discussion translated from the Spanish.)

Señores Solís and Guzmán.

through this meeting of eminent professional men, the present state of the art in the five technical subjects which make up the programme. They regret that this programme lies without the field of professional practice of their State, which is purely textile, and in whose capital, on account of its excellent climatic and topographic conditions, it has not been necessary, up to the present time, to introduce modern sanitary devices. On account of the extraordinary firmness of its soil, it has not been obliged to contend with exceptional foundation problems; and, as the center of an extensive network of railroads which has completely done away with care of the ancient roads, it has not preoccupied itself concerning the future fate of the public highways. The recent growth of automobiling, however, now compels attention to, and interest in, them. On the other hand, our capital being on the eve of establishing a system of drainage and all manner of sanitary improvements, the subject of potable water supplies also greatly interests the State, and, through the writers, it will secure, from the deliberations of this meeting, knowledge of the latest advances in all the important matters proposed for discussion, and the writers will endeavor to co-operate by discussing the two first questions of the programme presented, giving their opinions on these subjects on an abstract basis.

With regard to the first subject under discussion, the writers believe that, with the present state of knowledge and experience in the art of sanitation, only the second alternative stated in the question is practical, that is, to permit a certain amount of contamination, and to rely on a subsequent purification.

In truth the art of sanitation, in spite of the great advance that has been made in the acquisition of knowledge and of practice, has, up to the present time, only undertaken the sanitation of isolated and independent communities. In sanitary matters facts must be considered in their multiple condition, not isolating some with respect to others, because they are never independent. From this point of view it is of little use to attend to the sanitation of one city, if the valley or region in which it lies is not also taken care of, and in the sanitation of any region the disinterested co-operation of the various communities in it is indispensable.

Unfortunately up to the present time each community watches its own interests only, not concerning itself with the interests of the others with which, on account of local conditions, it is inseparably linked, and on whose healthfulness depends in great part its own. If a community does not dispose properly of its refuse, getting rid of it without special treatment of any kind, its final disposition being near neighboring communities, the latter will become contaminated, and disease will be developed in them which may infect the culpable community and even the whole region. Therefore, sanitation to be com-

plete and effective must be more than local, it must cover the entire region, and must embrace all towns that are linked by natural conditions; and as long as this desideratum of the sanitary art is not reached, the potable waters in such regions, whatever their origin may be, if they are below the level of the sewage of other towns, will be somewhat contaminated. Even granting great vigilance and control by the Governmental powers, the result will be the same, because unless such regulation is mechanical and automatic, it will be inefficacious. It is fruitless, therefore, to purchase and watch the water-sheds that feed the reservoirs, and, in the opinion of the writers, it is best to allow contamination to take place to a certain degree, trusting to filtration for purification. The question may well be asked: Is regional sanitation which will prevent the contamination of water possible in practice? Judged purely in the abstract, and by the theories of sanitary art only, an affirmative answer forces itself upon us, and, furthermore, that this is the only proper form. It is incomprehensible that any system which restricts its attention to isolated points can be called sanitary. The phenomena of life under whatever form we may consider them, be it individually or collectively, are always the same; and as, in the individual, health cannot exist unless it exists in the whole organism, in the same way, collectively, it will not exist if it does not encompass the whole region. Now, what are the fundamental conditions necessary to regional sanitation, in the strictest conception of the term? The very same conditions as are necessary in individual life, and, summed up, they may be condensed as follows: Continuous renovation; continuous renovation by circulation or motion; and continuous renovation by chemical or substantial transformation. In the life of the individual these conditions in their admirable harmony are regulated by what is known as "the vital principle," and in collective life they are, in turn, regulated by the laws of political economy, and the rights of the individual under the direction of the Government. It is within the field of political economy to arrange financially for the problem of continuous circulation by chemical or substantial transformation, and it is the arduous task of the Government to harmonize sanitary interests in such a way that the best interests of the whole region will be preserved. *Señores* Solís and Guzmán.

In the same degree as these difficulties are overcome, will the art of sanitation advance from being purely local, as it now is, to being regional, as it will be to-morrow, and in that same degree potable waters may be considered as safe from contamination.

In what degree has the scientific disposal of garbage been successfully and economically applied to the sanitation of towns? Much effort has been made in this direction, and results have been obtained, propitious in some cases, adverse in others, but thus far the advantageous results have not been confirmed by properly made esti-

Señores Solís and Guzmán.

mates, and the general opinion among sanitary engineers is that we have not arrived at satisfactory results, especially with respect to sanitation by gravity, in which process the matter being highly dissolved, its extraction is very costly.

Now while the art of sanitation remains in the precarious condition of not being able to get rid of detrimental matter except by the process of solution and removal, the contamination of potable waters is inevitable, and it is necessary to resort to filtration, which is the only solution of the situation in the present state of the art. But when the economical transformation of domestic and other wastes becomes possible, to the extent that it may be applied generally, and when the mental condition, customs, and altruism of the community have advanced to the perfection required by the present state of sanitary science, it will be possible to put its teachings into practice. The decisions of Boards of Health may then be carried out with efficiency, and then regional sanitation may be accomplished, and the non-contamination of potable waters will also be an established fact. In the meantime we must be resigned to allow potable waters to become contaminated, and we must purify them by filtration.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

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PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

FOUNDATIONS.

An Informal Discussion at the Annual Convention, July 10th, 1907.*

SUBJECT FOR DISCUSSION:

"(*a*) What is the best system of construction for foundations of heavy structures on ground such at that of the City of Mexico, which is an alluvial deposit about 300 ft. in depth, and similar in character to that at New Orleans?

"(*b*) Will iron or steel used in foundations, independently or in combination with other materials, last indefinitely when in direct or indirect contact with water?

"(*c*) Will the strength and durability of concrete in foundations be affected if before setting there is: (1) an excess of water; (2) lack of compression; (3) too rapid desiccation?"

BY MESSRS. LANSING H. BEACH, F. G. JONAH, G. E. P. SMITH, J. C. MEEM, C. M. MORSSEN, PABLO SOLÍS AND OCTAVIO GUZMÁN, AND M. MONEADA.

LANSING H. BEACH,† M. AM. SOC. C. E.—There are a couple of features connected with foundation work in a large city, which were not mentioned in Mr. Fuller's discussion, and which may be new to many members. Maj. Beach.

One point is, that it may be advisable to avoid the use of steel as far as possible on account of the danger of electrolysis. It does not follow that steel construction under ground will be safe because there is no danger at the time the foundation is laid. The use of electricity is constantly increasing, and it is a reasonable supposition that with the installation of new power plants, especially those operating under

* Continued from August, 1907, *Proceedings*.

† Major, Corps of Engineers, U. S. A.

Maj. Beach. a high voltage, and the deterioration of street car lines, there will be in future a greater quantity of electricity flowing through the ground than at present. A small amount of electricity traversing the steel of a foundation for several years, or a larger amount for a shorter period, must affect the strength of the combination. Such conditions do not obtain in the country, but there is an existing and increasing danger to the steel in foundations in every large city from this cause.

The other point is that in a city, where a building is apt to go to the property line, the engineer often does not have room to construct a foundation of such character as that which he would usually adopt for a structure occupying but a portion of the land owned. If the structure is on a line of railroad, or standing by itself, the engineer can easily extend the footings so as to obtain the required bearing limit, or he can often without difficulty compress the soil to the necessary degree. In a large city where the property lines are accurately marked and must not be crossed, and the owner desires to cover every inch of ground upon which he is entitled to build, there is no such thing as spreading the footings, nor is it always practicable to compress the soil without producing such a lateral movement as will affect adjacent buildings.

A man may desire to erect a building of a certain weight per square foot on his lot, and the engineer can devise a foundation which will produce stability in that structure, but in soft soil the adjacent buildings, if much lighter, may be lifted, bulged, or cracked, which may result in a lawsuit and perhaps further expense. In a large city with a yielding soil a man cannot build unto himself alone; his neighbors must be taken into account, and it often takes more time and money to avoid injuring them, than it does to provide for his own.

In a compressible soil containing a large quantity of ground water, there is great danger from the subsequent draining away of that water. It helps to sustain the load, and foundations which have stood and served their purpose for more than a generation, may fail completely upon its removal and the consequent compacting of the soil. The speaker knows of a building, which had stood perfectly for many years, and which has been completely destroyed in this manner.

Taking all things into consideration, it is believed that the engineers and architects of Mexico City have as difficult foundation problems to solve as are presented anywhere to-day.

Mr. Jonah. F. G. JONAH, M. AM. SOC. C. E.—Foundations for all heavy structures in New Orleans are now made of piling. This is the best foundation for that locality because, in the absence of bedrock or hardpan, piles give sufficient frictional resistance to sustain all necessary loads.

The soil of New Orleans is nearly always pure alluvium many hundreds of feet deep. There is, in various parts of the city, an

Mr. Jonah.

underlying stratum of shells and beach sand, usually 40 ft. below the surface and from 6 to 8 ft. thick. Piles can be driven through this, but it is not considered necessary to do so, and they are stopped in this stratum. This material was encountered in driving the foundation piles for the new passenger station now being built at Canal and Basin Streets, and in the foundations for the Hagan Avenue Bridge, 1 mile away, while, just below the city limits, where the new Frisco Docks are being constructed, and where more than 36 000 piles have been driven, alluvium was the only material reached. The same condition obtains on the work of the new Sugar Refinery, also just below the city limits, where more than 6 000 piles have been driven. On the dock work, which is under the writer's charge, 75-ft. piles have been driven in trenches excavated 15 ft. below the surface, so that for 90 ft., at least, there is nothing but pure silt. Careful records and experiments show that in this material a 60-ft. pile will sustain a load of 65 tons without settlement, although 16 tons per pile is the average load calculated. While these piles may be driven very quickly—as much as 4 in. per blow—it is often found that, if they stand partly driven over night, on resuming work next morning several blows are necessary to start them.

The writer has also noticed, in driving piles for trestles in New Orleans and vicinity, that while a pile might go as much as 1 ft. at the last blow, yet by the time the deck and track were on, the trestle would stand up under ordinary traffic.

The piles used are pine sticks, cut in Louisiana and Mississippi; they are very straight and smooth, will average about 60 ft. in length, 6 in. in diameter at the small end and 13 in. in diameter at the butt, and are now furnished and driven for from 30 to 35 cents per linear foot.

The occurrence of the sand and shell stratum in patches can be accounted for on the assumption that it formed part of the old coast line or probably formed small islands which were gradually connected with the mainland and covered by the upbuilding of the Mississippi Delta.

The great holding power of piles in this silt is due to the free lateral movement of the soil causing the pile to be firmly gripped as soon as driven. The extraordinary lateral movement of this soil, and facts relating to its depth and subsidence are referred to in the discussion by E. L. Corthell, M. Am. Soc. C. E., on the paper entitled "The Reclamation of River Deltas and Salt Marshes."*

In driving piles in this material some care must be exercised in their spacing, as it is possible to drive them too close to one another, in which case the frictional resistance would be measured

* *Transactions*, Am. Soc. C. E., Vol. LIV. p. 83.

Mr. Jonah. by the circumference of the cluster rather than by the circumference of the piles separately—3½ ft. is a fair average spacing.

This foundation is undoubtedly the best for New Orleans as the piles go below the level of basements, sewers and canals; and modern buildings are being erected on such foundations without any settlement. The foundations will also be permanent, as wood, in soil of this character, when carried below the line of atmospheric and moisture changes, lasts indefinitely. This has been abundantly proven in New Orleans where, in boring for wells, logs in good preservation have been encountered hundreds of feet below the surface. Recently, in excavating for the basement of the new passenger station at Canal and Basin Streets, perfectly sound cypress trees were uncovered 12 ft. below the level of Canal Street.

Excavations frequently expose old foundations on cypress footings in as good condition as when put in a century ago. These footings are usually from 4 to 6 ft. below the surface.

The drainage works of the city, now in course of construction, will probably lower the water level to 8 ft. below the surface, so that in the future timber foundations may not last as well as they have in the past, unless carried below that level, which of course, is the case with pile foundations for new structures which are provided with basements.

As to Mexico City, the writer has observed that the soil is not similar to that of New Orleans, for there is no underlying hard stratum; the hard stratum is on the surface, and is a material known locally as "tepetate," something like hardpan, overlying a great deposit of volcanic ash. With the drainage of Lake Texcoco, and the consequent lowering of the water level in the city, the surface soil is settling and carrying with it the buildings, and as the settlement is not uniform, many structures are being cracked.

The speaker believes that piles would be the best foundations in the City of Mexico; but, as the cost of timber would be excessive, the situation could be met with concrete piles. There might be some difficulty in putting down concrete piles of as great a length as the timber used in New Orleans, but a shorter pile, of greater circumference and with a greater taper, would undoubtedly answer, if it went below the water level and well below the level of excavations for basements and sewers.

As to the strength and durability of concrete being affected by an excess of water and lack of compression, this is one of the questions upon which the Engineering Profession has changed ground in the past fifteen or twenty years. Formerly, all specifications stated very definitely that an excess of water must be avoided; they contained the clause, "just sufficient to flush to the surface when thoroughly tamped," etc., etc., or, in other words, dry concrete was

almost always used. To-day the reverse is the case, as wet concrete —decidedly wet—is the rule. The speaker believes that no material injury arises from the use of a wet mixture, provided the forms are tight and do not permit the mortar or cement solution to leak out. This is a change brought about very largely by the contractors of the country. Where impervious concrete is required, the wet mixture will give the best results; also, in filling irregular forms with concrete the wet mixture will fill angles and corners in which it would be very difficult to tamp a dry mixture; consequently it gives the average job a much better appearance when the forms are removed. Mr. Jonah.

G. E. P. SMITH, M. AM. SOC. C. E.—In relation to the effect of rapid desiccation on concrete, the speaker's experience has been gained in a country where for days the temperature stands above 100° and the humidity below 10 degrees. On one occasion the local weather observer, interpolating outside the Weather Bureau tables, unwittingly reported the relative humidity as a negative quantity. The ground also becomes intensely dry, as there are often periods of from 5 to 10 months in which there is no rainfall to counteract the surface evaporation. Concrete work, however, is carried on throughout such seasons without interruption, and most contractors take no further precautions than are taken in humid climates. Mr. Smith.

Under such conditions, the effects of "too rapid desiccation" must be extremely severe, and if engineering structures are endangered from this cause the fact would be readily apparent.

One of the severest tests of concrete is in sidewalk construction, and some utter failures have been recorded. In one instance 13 miles of newly-laid sidewalk were taken up at once; and 3 miles of sidewalk laid this year are disintegrated to such an extent that they will be removed and replaced this summer; however, many more miles have been well built, and after years of service are in perfect condition without cracks or worn holes. Consequently, concrete sidewalks are still the most popular, and, from the municipal standpoint, the most satisfactory type in the arid region, which includes the Southwestern States, together with the northern half of Mexico.

It is found that certain brands of cement which are satisfactory for tunnel and heavy foundation work are positive failures when used for sidewalks. The rapid desiccation of the latter must, in part, account for this difference. On the other hand, most brands of cement do not suffer in this way. Concrete, for sidewalks and for other purposes, is usually mixed and laid, and sets in the ever-burning sunlight. After some hours, and when thoroughly set, it is covered with dirt or boards and wetted, and usually comes out in good condition.

Mr. Smith. As soon as set takes place, further desiccation can usually be prevented. In making cement pipe the speaker has kept the concrete wet for a week, but bridge piers are sometimes finished in midsummer with little or no sprinkling.

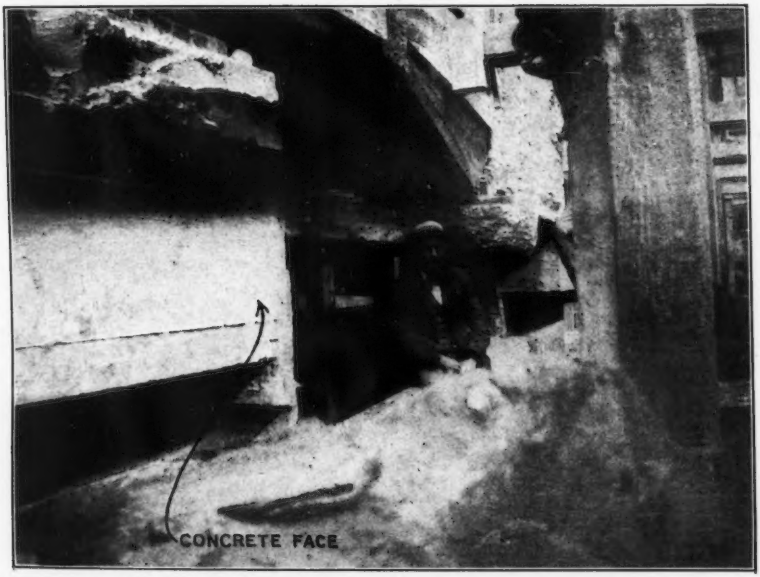
Where freshly-laid concrete is to be exposed to rapid desiccation a cement should be selected which is known to withstand such conditions. The defects of high-limed and uncured cements are probably accentuated by desiccation. A suitable cement, however, will withstand almost any conditions met in practice, and concrete work in the arid region is not limited by this obstacle.

Incidentally, it may be added that the aggregate used in Tucson, Ariz., is a basaltic lava, identical in composition and structure with that of Tlalpam, near the City of Mexico. This lava rock is also used for macadamizing the streets, and forms a well-bound surface without the aid of a roller.

Mr. Meem. J. C. MEEM, M. AM. SOC. C. E. (by letter).—Referring to the question of concrete in foundations being too wet or drying too rapidly, or the necessity for ramming, the results of some recent observations of actual conditions will be given.

In underpinning the buildings along the line of the Rapid Transit Subway in Brooklyn, it was sometimes necessary to go to a depth of 40 ft. below the curb line, the lower 4 ft. being sand below the level of mean high water. The method pursued in all cases was to cut out sufficient brickwork on each side of the pier to be underpinned just above the floor level and insert needle-beams (generally 20-in. 80-lb. I-beams, 18 ft. long) in sufficient numbers to carry the load. These were wedged up from a cross-blocking of heavy timbers, and cross-needle-beams were set into recesses cut in the piers, a middle beam being put through a hole cut in the pier when necessary. These beams were cemented and wedged to an absolute bearing, and were then grouted in so as to form practically a component part of the pier.

An excavation, about 8 by 8 ft. square, was then made under the foundation to a depth of about 4 ft., and supporting chains were inserted to carry the hanging portion of the foundation. A 6 by 6-ft. pit was then box-sheeted, that is, horizontal sheeting was used and set in by the well-digger's method. Cement was used in the back of the sheeting to insure filling all spaces, and holding the upper strata of loose sand in place. As soon as water level was reached, interlocking steel sheet-piling, about 5 ft. 6 in. long, was set up inside the pit in a 5 by 5-ft. square and driven down till its top was within 6 in. of the water level; then, without pumping, the sand was cleaned out to a depth of 4½ ft. and concrete was deposited through a chute until the pit was filled to about 1 ft. above the water line. Dowels of boulders or rods were left projecting



CONCRETE PIERS, SHOWING FACE AT THE OVERHANG.

from this in order to give a bond for the upper portion of the pier. As soon as the concrete had partially set, the remainder of the pier was filled in to within about 4 in. of the foundation level. After setting, this was grouted in with semi-liquid mortar, care being taken to fill every possible void by ramming and packing the grout well under the foundation. After about 5 days the beams were removed, a few at a time, and the holes in the brick-work were replaced with new masonry. Mr. Meem.

Plate LXXXVIII shows the face of two of the concrete piers at the overhang, where the 8 by 8-ft. space above the 6 by 6-ft. pit was filled in. The face shown is that left by the original boards used for the sheeting, and gives a fair idea of the satisfactory texture of the concrete. This concrete was made under the Rapid Transit Commissioners' specifications, and was composed of a 1 : 3 : 4 mixture of cement, sand, and gravel, the latter ranging from $\frac{3}{4}$-in. to $1\frac{1}{2}$-in. stone.

The deductions, from observations covering a large number of these piers, are:

(1) Concrete does not have to be rammed if put in sufficiently wet.

(2) In foundations, it is practically impossible, within the limits of common sense, to put in concrete too wet, always providing, of course, that the water is not allowed to run away.

(3) When concrete as wet as practicable is placed in foundations there is no danger of too rapid desiccation.

The writer believes that it is established beyond controversy that concrete should always be protected from drying out too rapidly, and when it is put in place very wet there is no need of protection, except where it is exposed to the direct rays of the sun in hot weather.

C. M. Morssen, Assoc. M. Am. Soc. C. E. (by letter).—The following is a brief description of three systems of foundations used by the writer with good results: Mr. Morssen.

Foundations by Reinforced Concrete Coffer-Dams.—A coffer-dam, 30 by 12 ft. in section, and 15 ft. high, was built above the ground, in which it was to settle down. The water was taken out by a centrifugal pump, which removed 2 cu. yd. per min. This pump was driven by an electric motor erected on top of the coffer-dam. The dam was lowered by excavating inside of it, the vibration of the motor in the coffer-dam proving of great assistance in working it down. The advantages of this system are:

1st.—A coffer-dam, of the proper dimensions and of the same height as the depth to which it is to be sunk, can generally be built above the ground. The motor,

Mr. Morssen.

pump, and suction pipe being fixed on top of the structure, and the suction pipe being of a definite length, the work may be carried on steadily, as no cessation is necessary from time to time to lengthen the pipe, as is the case with other systems.

2d.—Absolute safety for the workmen.

3d.—The motor's vibrations, combined with the great weight of the coffer-dam, ensure a regular settling of the dam.

4th.—The walls of the coffer-dam, being reinforced, act as very strong beams, and, when big stones, wooden timbers, or pipes, are encountered, an aperture can be made under the wall of the dam without injuring it, thus permitting the removal of the obstruction. After the dam has been sunk to the required depth it is filled with concrete, and thus forms a very solid foundation.

The general arrangements are shown in Fig. 1.

Foundations by Reinforced Concrete Piles.—Reinforced concrete piles may be used in soils of weak but uniform character. Such piles are cast in vertical or horizontal moulds, and, after the concrete has set (in from 6 to 8 weeks), may be driven in the same manner as ordinary wooden piles. The precaution must be taken, however, to protect the head of the pile from the blows of the hammer by a special helmet. Each pile is reinforced by from four to eight round iron rods, and iron shoes are fixed on the bottom of the pile. Good results are obtained by driving with a very heavy hammer, falling a short distance, and giving a large number of blows per minute. For the foundations of some bridges built in Europe the writer has driven piles 50 ft. long and 16 in. square, and the results were much better than were anticipated.

Reinforced concrete piles have been used extensively for foundations in London, England, as there wooden piles are soon destroyed by worms.

As the friction between soil and concrete is of great numerical value, in many instances the piles need not be carried down to solid ground. Further, as reinforced concrete piles cannot be destroyed by insects or external causes, they provide a reliable foundation in such cases. One of these piles, 50 ft. long, driven in a middling soft bottom, requires from 4 000 to 5 000 blows, but, by using water under pressure, the pile can be driven home more quickly. The water can be conveyed by an iron pipe embedded in the concrete, or by simply leaving a hole in the center of the pile. By using water under pressure, from twelve to fifteen piles, from 40 to 50 ft. in length, can be driven in a day by one driving ma-



THE COMPRESSOL PILLAR AS IT APPEARS IN THE SOIL.

chine. The cost of these piles depends largely on the number required (as the initial installation is very expensive), and varies from \$1.50 to \$5.00 per lin. ft. of pile driven, the greater the number of piles the less the cost per foot. Mr. Morssen.

The driving of reinforced concrete piles shows in a marked manner the great adhesiveness of concrete and steel, as the pile,

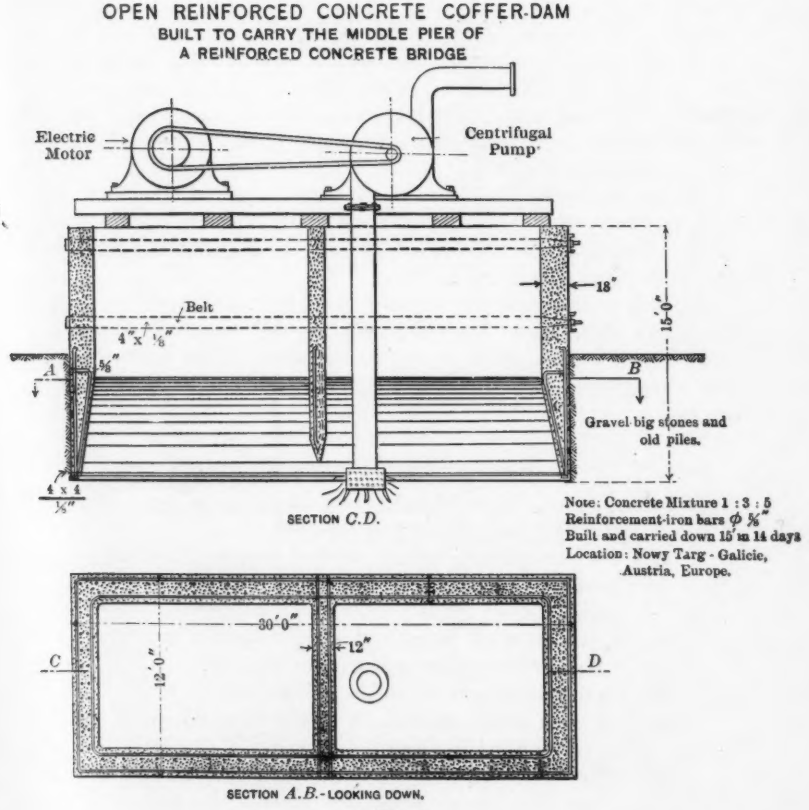


FIG. 1.

before it is completely driven, has to stand very heavy blows and much vibration, and the endurance of the combination speaks well for reinforced structures as a whole.

This process is illustrated by Fig. 2.

Foundations by the So-called "Compressol" System.—The idea of this system is to make a hole in the ground by lateral and verti-

Mr. Morssen. cal compression of the soil, the cavity thus made being afterward filled with concrete. A specially designed pile-driver lifts what is styled a "perforating rammer," of conical shape, weighing from 2 to 3 tons. This rammer is dropped from a height of from 25 to 30 ft., and its fall compresses the soil laterally and vertically, until in a short time a hole is formed in the ground. The hole can be carried to the required depth by dropping the hammer repeatedly. Owing to the great weight of the hammer and the height from which it is dropped, the soil is closely compressed, and temporarily rendered water-tight. In cases where the soil is too soft to give a close hard surface a certain amount of lime may be added during the perforation. This lime is firmly compressed against the sides of the hole, rendering them water-tight for the period necessary to place the concrete.

When the cavity has been made of the desired size, it is filled with concrete which is tamped down with a rammer of a special shape. Owing to the thorough tamping, the concrete spreads in the hole and forms a very strong pile.

In many instances the volume of concrete required is four or five times larger than the hole itself, as the ramming of the concrete causes it to expand in every direction. This expansion further strengthens the foundation by the additional compression of the soil.

The method of forming the columns is indicated in Fig. 3.

The chief advantages of the "Compressol" system are:

1st.—It gives absolute safety, by enabling pillars to be built of the desired bearing capacity.

2d.—No excavations which weaken the soil are necessary; on the contrary, the soil is strengthened by compression.

3d.—It obviates all danger to which laborers working below the surface of the ground are subject.

4th.—All operations are done mechanically.

5th.—It is a rapid method—a pillar from 25 to 30 ft. deep can be filled in from 3 to 4 hours.

6th.—The concrete, tamped down with very heavy rammers, percolates every weakened part of the soil, and gives it the required strength.

The "Compressol" system has been used in numerous cases and in many kinds of soil, and has given very good results. It has been used for the foundations of many bridges and buildings in France, Germany, and Egypt.

The cost of a pillar having a carrying capacity of from 90 to 100 tons is from $35 to $55.

Mr. Morssen.

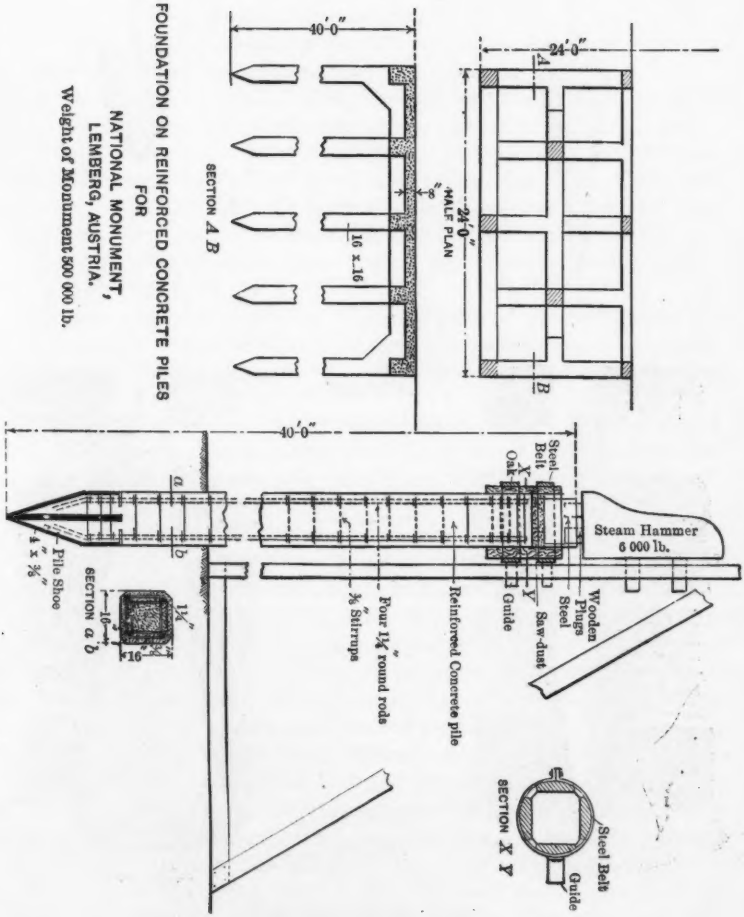
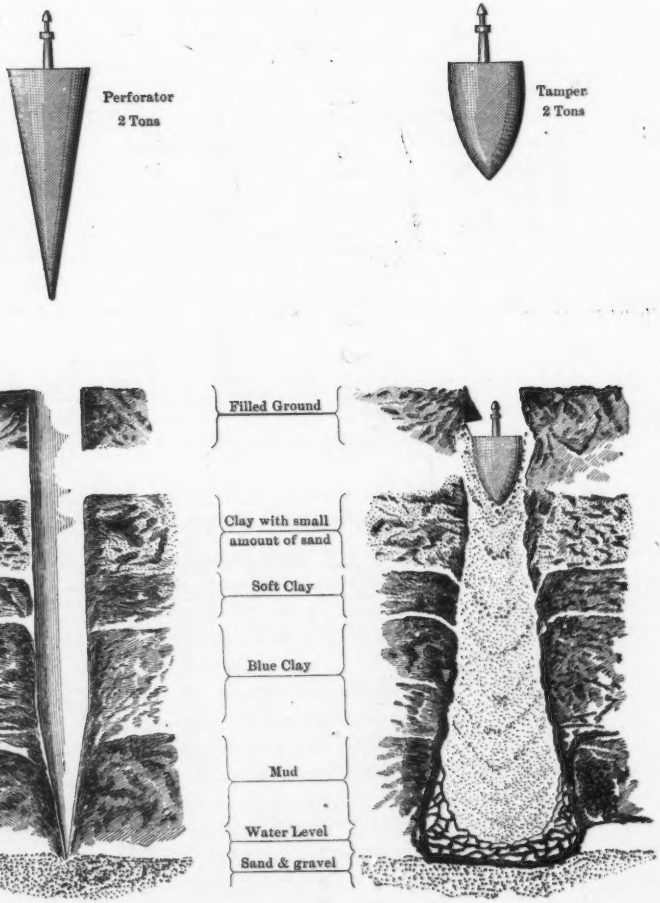


FIG. 2.

Mr. Morssen.



TAMPING AND FILLING

FIG. 3.

In conclusion it may be stated that either of the three systems described herein may be used in any ground under heavy structures, and it is the writer's belief that such foundations would give good results in such ground as that of the City of Mexico. Mr. Morssen.

It is impossible to assert that any foundation will last indefinitely, yet iron or steel embedded in a rich concrete mortar will remain in perfect preservation as long as the concrete itself exists. The durability of concrete is fully proven by the Roman remains in that material which are unearthed from time to time.

As a practical illustration of the durability of iron and concrete when in contact with water, the case of a concrete wharf at Grenoble, France, may be quoted. This wharf, after having been in existence for about 80 years, was pulled down, and many iron tools, nails, and anchors were found accidentally embedded in the concrete, and all were in good condition. On the other hand, iron used independently, for foundations affected by water, soon rusts; and its entire destruction is merely a matter of time.

The writer can state definitely that an excess of water does not affect the strength and durability of concrete foundations, if the water to which such foundations are exposed is at rest or quite motionless while the concrete is setting.

The strength of concrete is affected seriously by lack of compression when it is put in dry, as its value depends on its density, and, unless thorough compression or tamping takes place, the body will be "spongy" and not fit for its purpose.

If, during setting, the desiccation is too rapid, the shrinkage or contraction consequent thereon will cause cracks to occur in the concrete, which, of course, will affect its strength seriously.

Señores Pablo Solís and Octavio Guzmán* (by letter).—This theme belongs to the Engineers of the City of Mexico and New Orleans, and, as specialists upon the subject in question, it is hoped they will place their opinions before this Society. By their experience, which has been recorded in special articles, we have been informed, that in soils of this nature, foundations of masonry are inefficient, because they yield and sink; that piling has not given good results, as may be seen by the bad condition of the ancient buildings of Mexico with this type of foundation; and, also, because this soil is so indefinitely compressible that a final settlement of the piles is never obtained. It may be observed that piles sunk to the limit of "the rebound of the hammer," continue to sink when, within a short time, they are subjected to further driving from the same hammer. We have also been informed that the practice of deep foundations is not good, because it does not diminish the settlement and necessitates laborious drainage, *Señores* Solís and Guzmán.

* Delegates to the Convention of the American Society of Civil Engineers from the State of Puebla, Mexico. (Discussion translated from the Spanish.)

Señores Solís and Guzmán.

and that, on account of the currents produced in the subsoil by such drainage, these excavations are the cause of the cracking of many of the old buildings nearby; that foundations with sand have been successful in the construction of the Teatro Nacional; and that experience shows that the best construction for Mexico is the grating form, whether a grate or platform of wood or iron is used, or a monolithic plate of "beton" or equivalent material. This process it is understood gives good results, because, by means of it, the following requisites which are indispensable for a good foundation in Mexico are obtained:

(1).—The distribution of the total weight over the largest possible area so as to diminish as much as possible the intensity of the load.

(2).—The shallowness of the foundation which avoids laborious drainage, which drainage causes internal currents resulting in damage to contiguous buildings.

(3).—The distribution of the load, so that its intensity will be the same at all points, if the ground is homogeneous and uniformly compressible throughout; and, if not, then the distribution of the load proportionately, so that its intensity does not exceed the reaction of the ground at any point. Finally it should be noticed that the builders of this capital, upon whose authority these observations are based, fix ½ kg. per sq. cm. as a safe load limit for foundations, and as a maximum load, which should be exceeded only in very special cases, 1 kg. per sq. cm., figures that represent the reaction of these soils.

The preceding facts give the essence of the usual practice in foundation construction upon the soils of Mexico City. Said facts or figures would give of themselves an adequate answer to the first part of the question under discussion, were it not that they refer exclusively to the condition of the subsoil of this city prior to the construction of the drainage and sewerage systems. Since these improvements, however, the quality of the subsoil has changed, and, therefore, as the data have changed, the process of foundation building must change. To what extent and in what manner practice in foundation work will be modified is not known, and the writers have many doubts which may be formulated in the following questions: What changes have been wrought in the subsoil by the drainage of the city? Has the modulus of ground reaction changed? To what depth has the water level dropped? And, if it has dropped but little, should present foundations for this capital go down to "water-saturated ground," or should we build them superficially in the desiccated strata?

With respect to the last question, the writers believe that foundations should be built upon the surface of the diluted soil, for there the ground being semi-fluid, the water, on account of its incompressibility, acts as a powerful medium of reaction against the weight of buildings, and, to a certain extent, in accordance with the principle of Archimedes that a submerged body loses a part of its weight equal to the

weight of the water displaced by it. From this point of view it may be considered that foundations upon gratings in soils as saturated with water as these in question, owe their efficacy against sinkage of the load they carry to the fact that they are, we might say, floating. The ancient buildings of this city built upon gratings are still in excellent condition. On this account also, modern construction companies are justified in constructing in the City of Mexico foundations with huge gratings of steel, iron and beton, and are also justified on account of the changes in the subsoil since the drainage in extending foundations to cover not only the base of the wall, but the whole area of the building, as has been done recently in the magnificent building for the Messrs. Boker. *Señores* Solís and Guzmán.

In closing, the writers will refer to the last part of the topic under discussion: "Will iron or steel used in foundations, independently or in combination with other materials, last indefinitely when in direct or indirect contact with water?"

As mixed foundations of this nature are of very recent installation, it is not possible to find history concerning them that might be useful in passing judgment upon this subject. On the other hand general and numismatic archæology might contribute some data, especially the latter, as for instance in the case of Chinese iron coins, now found in museums, and which may have been for many years under water.

With respect to iron in salt water, it is known that, in the Harbor of Vigo, when the treasure was taken from some American galleons which had been sunk in Colonial times in that harbor, iron cannon were found with that treasure, the metal of which was extraordinarily altered and softened to the consistency of wax. We also have knowledge of the iron taken from the breakwater at Brest, which had been immersed for a century and was found half destroyed, the material, as attested by M. Lidy, Civil Engineer, containing hardly 56% of free iron, the remaining portion being in very bad condition, with the internal fibers almost destroyed, showing many eaten out spots. Both these cases, however, should be discarded, because the destructive effects were due to marine salts.

With regard to fresh water, we have no knowledge of data that would show how iron behaves after an indefinite period of immersion; the iron of hydraulic wheels, canal gates, and many other objects used in the industries, permanently immersed, apparently remains well preserved when subject to the continuous or, at least, to the frequent flow of water. In these cases deterioration due to wear by friction of water is greater than that due to oxidation, and, as the renewal of parts happens slowly, and original shapes are always retained, the illusion of the immortality of the metal is produced, which in reality is only perpetuity of form. In still waters oxidation is more rapid,

Señores Solís and Guzmán.

but it reaches the interior of the metal very slowly, the first coating of oxidation formed, becomes a protecting coat against the propagation of this deterioration, and a condition of permanent equilibrium and preservation seems to become established. Iron buried in foundations invaded by water is subject to these conditions exactly, and as the mass of the foundation is strongly compressed, the lack of air renewal is complete, the temperature low and uniform, and the oxidizing forces are paralyzed. It is probable that iron in foundations, under these conditions, if it is not indefinitely preserved, at least its deterioration must take place very slowly; and as this deterioration consists in the chemical change of one body into another, the result, under the constant powerful action of the weight of the building, can only cause, in its turn, a very gradual settlement of the foundation, until, by necessity, a final settlement is reached. This will be the result even though the mass of iron is finally changed to a mass of oxide of iron, since it is probable that, on account of the constant pressure to which it is subjected, hollows could not be left in the mass.

On the other hand, the spirit of the present epoch is not as conservative as that of the past, and does not occupy itself with the indefinite conservation of things, because we know better than those before could have known, that the exigencies of progress, in its continuous necessity for new adaptations, demand less durability in modern processes. In reality, the formidable hardness of ancient structures, on account of the great labor of pulling them down, was more of a bane than a benefit to those who came after, as well as a profit to the industry of explosives.

Besides, studying the subject from the point of view of preservation, there is nothing disquieting, the remedy for which is not within the reach of modern science. If iron should not keep well in water, recourse to a covering of cement will preserve it.

Since reinforced concrete has come into general use, it has been noticed that iron remains unaltered in cement. After years the metal shows no vestige of oxidation, and preserves the bluish tint that it has when fresh from the milling machine, and there is no reason to believe that this preservation should not be indefinite, even in the case of submerged structures. The protection of cement must by force augment with time, as masonry of cement continues taking from the air or water new powers of durability and resistance.

Can there be a doubt of the practicability of preserving iron indefinitely under any circumstances, since Nature has shown us its numerous resources in the case of the preservation, in the ruins of Pompeii, deep under a layer of ashes, fresh and intact for many centuries, not only the unstable human organism, but even the transient and fleeting expressions of the anguish of death preserved upon the faces of those there buried?

In conclusion, the writers present the following summary of their views upon this subject: *Señores* Solís and Guzmán.

First.—There is no practical experience as to the indefinite preservation of iron in water.

Second.—By reasoning, it seems evident that iron will be preserved in the water of foundations without special preparation.

Third.—There seems no reason for worry about an indefinite preservation of this material. It need only be preserved within time limits which are governed by the growing necessities of readaptation by modern progress.

Fourth.—That if it were deemed advisable to preserve iron indefinitely in foundations, it is possible to do this by having recourse to science.

The abstruse plane in which, almost exclusively, the writers have taken up this discussion, on account of their small personal experience, is as fertile in wise conclusions as is the field of experiment and the elucidating figures of statistics; the process used, therefore, is, due to lack of others, as good as any. If the derived conclusions lead to error, the writers will listen with pleasure to any remarks and objections, and honestly bear the full weight of their errors.

Señor M. MONEADA (by letter).*—The lowest ravine of the valley of Mexico must have been at some time filled with rocky promontories, like Chapultepec, Peñon de los Baños, Peñon Viejo, Flahna, etc., which projected above the waters of the lake or above the flatlands. The stratum of alluvial deposits which was subsequently formed is on this account of varying depth, and when it became dry land there remained a soil of light consistency seated upon water. The Spaniards when constructing heavy buildings resorted to the old and excellent system of piling, which gave good results in some cases and bad in others, as, for instance, the Church of Loreto, and the Mineria. *Señor* Moneada.

The writer believes that these varying results were due to the difference in depth of the semi-solid and compressible strata forming the surface. This theory would explain the uneven sinking of the Mineria, taking for granted that at the northern and southern sides, where it has sunk least, there exists a rocky subsoil at a lesser depth than at the eastern and western sides.

The trouble due to the slight and uneven solidity of the ground in that epoch was considerably increased by the drainage of the valley, for as the level of the lake waters fell, the waters with which the soil was saturated fell also, and a porous and more compressible soil resulted. It is desirable, therefore, to solidify the soil evenly and sufficiently at the least expense. It is very expensive to make deep excavations and fill them with I-beams and cement, and, in some cases, useless, for, although on account of its rigidity this heavy platform

* Translated from the Spanish.

Señor Moneada.

will not rupture, it might move into an inclined position upon its foundation of uneven resistance, and the building upon it be thrown out of plumb.

It might be well to take the following steps:

(1).—Examine the nature of the soil upon which the building is to be erected by means of artesian well borings of not more than 30 m.

(2).—Drive piles varying in length and number, according to the comparative weakness of each part. The displacement by driving the piles will cause lateral compression, and the soil will become more solid. These piles are indestructible, as has been proved by those which were driven many years ago and are still in good condition, but even if time should destroy them, the ground would retain its vertical resistance, and in this way the firmness of the soil would be equalized as much as possible.

(3).—Upon these piles the platform could be constructed of a minimum thickness, sufficient only for solidity.

(4).—Upon this platform, which would be 2 or 3 m. below the street surface, the walls could be built, but built broader at the base than at the street level. In this way the desired strength would be obtained, and useless filling between contiguous walls would be avoided.

(5).—All back-filling would be done with the earth from the excavation, and the cement or hydraulic lime of the walls thus covered would harden more after setting.

Upon a foundation of this nature, steel buildings with stone "coating," or lighter and cheaper reinforced concrete buildings, may be built.

A structure built upon a platform that has settled unevenly might perhaps be straightened, though with difficulty, and to do this a trench of convenient width and depth should be opened on each side of the parts which have not settled. The weight of the building would then force the earth under those parts to slide to the bottom of the trench, all lateral pressure being removed, and the building would plumb itself. It would be necessary, however, to study many problems of resistance to obtain good results.

The writer believes that iron buried in foundations and protected with mortar will keep indefinitely, for there is no constantly renewed supply of oxygen, as is the case in water and still more in air.

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PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

PAVEMENTS.

An Informal Discussion at the Annual Convention, July 10th, 1907.*

SUBJECT FOR DISCUSSION:

"Will the paving materials of the present be used in the construction of the pavements of the future?"

BY MESSRS. HORACE ANDREWS, GARDNER S. WILLIAMS, LANSING H. BEACH, E. M. T. RYDER, WILLIAM H. LAWTON, PHILIP W. HENRY, AND B. BIENENFELD.

HORACE ANDREWS, M. AM. SOC. C. E.—The subject as announced seems rather vague. Judging from the opening paper and discussions, the question might have been altered so as to read: "In what manner will present paving methods be changed in the future, and what materials will be used?" As almost all possible materials have been used, up to the present time, it is pretty safe to say that the materials of the future will comprise those that have been used in the past. Mr. Andrews

Paving materials may be divided into two classes: inorganic, such as stone or brick; and organic (those containing carbon in chemical combination), such as asphalt and wood. The latter class is more unstable than the former, and is liable to depreciation and decay from causes which have no marked effect upon inorganic materials.

At present, under certain conditions, the organic pavements seem to give good satisfaction and to withstand the trying impact of the iron-clad hoofs of horses with little wear and with a minimum of noise. The observations of the speaker within the last few weeks indicate that in the cold climates of our northern cities, Buffalo, Montreal, Albany and New York City, asphalt is disintegrating from causes

*Continued from August, 1907, *Proceedings*.

Mr. Andrews. other than heavy traffic or the abuse of cuts for trenches. A chemical change, or some loss of volatile constituents, seems to be responsible for these depreciations, which are widespread to an alarming extent. Perhaps this breaking up of the asphalt is due to great changes of temperature; at all events, it is not noticeable in the City of Mexico, nor has it been observed by the speaker in Washington.

If chemists can ascertain the exact treatment necessary and the precise kind and quantity of asphalt needed for any given climate and combination of sand or broken stone, so that present uncertainties may be avoided, the continued use of asphalt will be better assured.

Asphalt blocks laid with the smallest dimension vertical, or as horizontal slabs, so as to simulate sheet asphalt, do not seem to be a successful innovation. A pavement so laid is going to pieces very rapidly in the City of Albany. Perhaps it is the well-known tendency of a slab to rock and move under traffic that facilitates its destruction, especially where cold causes shrinkage, opening of joints and brittleness of the asphaltic mixture.

The speaker has given some thought to the effect upon the condition of a pavement, which is due to covering the soil with a water-proof roof of pavement, thus lessening its normal supply of water from rains. Sometimes the sidewalks are also nearly water-proof, and then the water contained in the soil's interstices can only be drawn from below, and in lesser amount, by capillary attraction. It is reasonable to suppose that the normal proportion of water is reduced by a water-proof covering, and that a shrinkage of the subsoil beneath the pavement may then occur. The speaker has observed a settlement and cracking of impermeable pavement which replaced cobblestones, where the subsoil was a pure clay. Such settlement is difficult to explain under any other hypothesis than that mentioned.

A secondary question arises: "Will the traffic of the future be of the same nature as that of the present?" Within a few years there has been a rapid increase in the use of motor vehicles and the adoption of elastic tires. At present these do not materially affect traffic conditions, for horses are as numerous as ever, but who can say that this use of horses will not cease at some future day? In that case many alterations in paving methods may ensue. Already strips of brick pavement in macadam roads are proposed, in order to avoid the raveling of the latter by automobiles. Such a combination is now being adopted on one avenue in Albany.

The advisability of the comparison of the wear of pavements by some scientific process involving a census of traffic is obvious; but in taking such a census, the personal equation may be large. The observer must guess at the weights of the contents of many loaded wagons, and his guess will materially affect the results.

In reducing a census of traffic to tons per linear foot of width of

carriage-way, the deduction of the street railway tracks from the width of the street produces a marked uncertainty in the result. In places, the existence of street railway tracks may add to the traffic on the adjacent portions of the street, but this is not invariably the case, nor is there an equality in this respect in all parts of the same street. Mr. Andrews.

In studying certain traffic statistics the speaker has been in a quandary as to the value of the ton used. A difference of more than 10% will exist, depending upon the use of 2 000 or 2 240 lb. for the ton. The weight of the ton used is not stated in some instances. If traffic statistics should be expressed in kilogrammes per meter of width, this uncertainty would be done away with, and international comparisons would be easily possible. The material of the vehicles' tires should be noted in the census. It would be a matter for congratulation if some well-recognized body should inaugurate a change in the metrical system, as above suggested, and should also formulate regulations for observers of traffic, with sufficient minuteness to render possible exact comparisons between different pavements in different cities.

The speaker is of the opinion that, in the severe climates of northern cities, well-laid pavements of inorganic materials are more likely to be satisfactory than others, and he would not overlook the possibility of making an entire pavement, including the wearing surface, of cement concrete. A pavement of this description has given good satisfaction for some years in front of the Capitol at Albany, and seems well adapted to automobile traffic.

Asphalt and wood may be used where the expense will not prove a hardship to the taxpayers; they are in the nature of luxuries, like rugs and carpets on floors. Cities with mild climates, or where the lasting qualities of these perishable materials may be prolonged by other favorable conditions, may use these organic materials more freely than their less fortunate or less wealthy neighbors.

Mr. Tillson has referred to an improved asphalt pavement "made up of a 6-in. concrete base upon which is laid 2 in. of a solid binder, covered with a 1½-in. wearing surface." A pavement was constructed under the supervision of the speaker and after consultation with Colonel Greene, of the Barber Asphalt Paving Company, on Center Market, in Albany, in 1889, which was very closely in accord with the suggestion quoted. This pavement is still in good condition and has never been repaired.

The speaker is of the opinion that granite pavement may be improved by the use of stone showing some stratification, since better-shaped blocks may be obtained with such stone, and their wearing qualities are often excellent. Some method of improving the exactness of shape of stone paving blocks is certainly to be desired.

GARDNER S. WILLIAMS, M. AM. SOC. C. E.—The speaker would call attention to one phase of paving, which appears to have been wholly Mr. Williams.

Mr. Williams. overlooked, namely, the sanitary question. There is something in a pavement besides wearing qualities and costliness. An ideal pavement should be one which, with a good wearing and noiseless surface, does not give off dust, nor allow the germs which may accumulate upon it to be blown away until they can be removed by the proper agents. It is known, of course, that there is a vast difference in the surfaces of pavements in this respect and that, so far as they have gone, experiments have shown the very worst in this respect to be sheet asphalt, the best to be cedar block, and other pavements to be intermediate between these two. The speaker does not wish to be understood as saying that cedar block is the best pavement, or that it is likely to be the one adopted as ideal, but the germ-disseminating quality of a pavement is a question of prime importance, and it is a matter for surprise that none of those expert in the subject under discussion appear to have ever thought of it.

It may be said that experiments have been made by locating gelatin or agar plates at specific distances above different pavements, under various conditions of cleanliness and wind, and observing the development of bacteria on the plates; observations of the presence cr absence of dust have also been made on windy days, and such investigations have shown that the number of germs and amount of dust in the atmosphere were far greater in the case of sheet asphalt than any other, and far less in the case of cedar block.*

Maj. Beach. LANSING H. BEACH,† M. AM. SOC. C. E.—In many respects, the question of pavements is very similar to that of clothes. What is suitable for one man and one occupation is not the best for another; what is well adapted for cold weather in a northern climate is by no means that which would be selected for summer in a southern latitude, and then, too, many men wear not what they would like, but what they can afford. Similarly there is no one pavement which possesses all advantages, is best for all climates and kinds of traffic, and adapted to the purse of the poor village as well as to that of the rich metropolis. There is no such thing as the best pavement for all towns and highways any more than there is a best kind of clothes for all men under all circumstances.

The first and principal use of a pavement is to keep pedestrians out of the mud and to make traction sufficiently easy to permit the hauling of relatively large loads. The result is that the first road covering is generally of the cheapest class, often not worthy of the name of pavement. Broken stone, cobble-stones, gravel and shell have been used where such materials are obtainable at small cost. When these are not so easily procured, the community resorts to such makeshifts as the vicinity offers. Cost varies so greatly with the locality and

* See *Engineering News*, Vol. XLIV, p. 242, for a description of a series of such observations.
† Major, Corps of Engineers, U. S. A.

Maj. Beach.

the materials which that locality offers, that no general comparison of expense is possible. For instance, in some parts of Ohio where paving brick are made in large quantities, vitrified brick pavements have been laid in some cases at a price as low as 35 and 40 cents per sq. yd.; this is less than the cost of macadam in many cases. Even the cost of as simple a covering as macadam varies greatly, depending upon the cost of quarrying and crushing, and length and character of haul. Cases are known where all the conditions were most favorable, and the cost did not exceed 25 cents per sq. yd.; in others, not so fortunate, the cost of similar work has been more than $1 per sq. yd. Sheet asphalt varies greatly in cost, depending upon the transportation necessary to bring the asphalt to the site. In Washington, where it can be brought in vessels, the cost is generally less than $2 per sq. yd. upon an 8-in. concrete base. In the interior of the country, the cost is higher under similar specifications. Brick pavements vary less in price perhaps than those of any other material, owing to the numerous places where such brick is made and the correspondingly large number of centers of distribution. Several of the large European capitals, London and Paris, for instance, use a wooden block pavement laid upon a thick concrete base, that in London being ordinarily 12 in. deep. The woods used are largely from Australia and New Zealand, and the cost of the finished pavement is between $4 and $5 per sq. yd., usually nearer the latter figure. There are few municipalities which can afford such an expensive covering for their streets and avenues. For a small village, or one of our new towns, with their comparatively light traffic and limited means, to attempt to use such a pavement would be as consistent as for a bricklayer or an engineer to wear broadcloth at his work.

The question of cost of a pavement includes not only that of first construction, but also the money which must be spent for maintenance. A macadam roadway traveled by many vehicles becomes costly to keep in proper condition, if the stone is at all soft, and is hardly ever an economical road covering from the maintenance point of view. Some asphalt block pavements upon residence streets in Washington have not required an expenditure of a dollar for maintenance in fifteen years.

The matter of repairs to a pavement is often, if not generally, discussed as if it were one of maintenance solely, but the fact remains that the closing of plumbers' cuts, or water-pipe or sewer trenches, or other cuts, so freely made even in new pavements, is different and requires different treatment. It is one thing to renovate the whole surface, it is another to put a patch in a good pavement so that it will not show that it is a patch and be a blemish upon an otherwise fine-appearing surface. For invisible patches, sheet asphalt is as good as any, perhaps the best, as cuts can be covered by it so as to be in-

Maj. Beach. conspicuous to a high degree. This sheet asphalt possesses, however, one great disadvantage in a town in which there is not enough of this kind of pavement to justify the establishment of a permanent asphalt plant within its limits. Cuts or trenches in such a case must wait for permanent repair until the traveling plant can make its annual or semi-annual visit to the town. This will often be found to be an important element in deciding smaller municipalities to use brick or block. A cut in a block pavement can be repaired by a good mechanic at any date desired, and need not wait for the arrival of outside parties. That many such cuts are carelessly or negligently repaired does not detract from the advantage. With proper care brick or block laid upon a cushion coat of sand or fine gravel can be relaid so that the patch will not be out of shape with the rest of the street, nor unduly conspicuous. If the city employs incompetent workmen, or does not insist upon the competent man performing his task properly, the defect should be charged where it belongs and not to the pavement itself.

The heat-retaining power of a pavement is a feature which seems to have been completely overlooked, and yet it is one which must exercise a great influence upon the comfort of the people living along the street, especially in southern latitudes. Some years ago the speaker made some experiments in Washington, which showed that macadam absorbed less heat than asphalt block, and that sheet asphalt absorbed more than any other kind of pavement. The amount of heat retained by it was sufficient to affect materially the temperature of the vicinity in hot weather. A city with a large number of asphalted streets must be hotter in summer than one with pavements of other materials.

The question is often raised as to whether or not a pavement excludes the moisture from the soil beneath it. The opinion formed from observations extending over several years in Washington was to the effect that in prolonged dry spells there was more moisture under the pavement than under the grass-covered places. The latter contain more water immediately after a heavy rain, but apparently the water, gradually diffusing itself through the ground, is retained under the pavement, while it evaporates from exposed places.

In Mr. Tillson's discussion sheet asphalt, asphalt block and bitulithic are mentioned as the varieties of asphalt pavement. There is another variety which has been coming into use in some of our smaller towns, and, while too new to permit of definite decision as to its merits, seems to promise well as an inexpensive road covering in many localities. It is formed by raking or harrowing the road surface, then sprinkling it with fluid asphalt and afterward rolling it. The method is one which may be considered as half way between the oil sprinkling of roads and the bitulithic pavement. Tar has been used in some cases instead of asphalt and appears to give good results.

After satisfactory results with one pavement, many engineers are

inclined to recommend it to the exclusion of others, but they should be careful to advise their clients according to their needs, or, at least, to show them the merits and disadvantages of the different materials and let them make their selection with a proper knowledge of the consequences. Maj. Beach.

E. M. T. RYDER, M. AM. SOC. C. E.—The speaker wishes to emphasize one point, namely, that of repairs. To a street railway man this is a serious question. The pavements of the present time are certainly not all that can be desired, and it is to be hoped that something will be discovered which will be an improvement. If joints in the track could be gotten rid of, the present trouble would be greatly diminished. The use of cast, thermit, or electrically welded joints has been considerable, but is not universal by any means. It is necessary, for instance, in the case of electrically welded joints, to have several thousand of them before it is economical to bring an electric welding plant to take care of them. It may as well be admitted that it will be necessary to take up joints in the track every once in a while, and, therefore, a pavement which would admit of doing so readily would be preferable. The pavement should be designed, not merely with reference to long life under favorable conditions, but with reference to its repair under conditions which will actually obtain. This is especially true in work where it is desired to use T-rails. There is a marked preference on the part of many city engineers for grooved rails, which undoubtedly have certain advantages, but it is an open question which type of rail is preferable, all things considered, and the decision must rest on local conditions. Mr. Ryder.

In Connecticut, most of the steam and trolley roads are controlled by the same corporation, and in certain localities it is considered very desirable to run trains, single cars, or possibly trains of two cars, from one city to another, over the main-line tracks of the steam road, and then in on the city streets in order to avoid transfers and to take people just where they want to go. This plan would afford a most convenient way for the people of the smaller towns to travel to the larger ones to transact business or to shop. In order to run trolley cars on the steam road, between the steam express trains, however, the same rate of speed is necessary for both. It would be unsafe to use the smaller flanges of the ordinary street-car wheels, or anything less than the M. C. B. standard dimensions, which practically means the use of T-rails for the street-car tracks. The only solution at the present time is to use granite dimension block along the rail, probably both inside and outside. In laying this granite block, the speaker prefers to use a tar or sand joint instead of a cement joint, because it is then more practicable to remove and replace the pavement for inspection and repairs.

A second and, of course, most important point in regard to pavements is the foundation under the track, as that often materially af-

Mr. Ryder. fects the life of the pavement. In towns where there is a good gravel foundation, no special preparation is necessary, but in some cities, where the soil is practically a brick clay, it is a very different matter. The company with which the speaker is connected has tried so-called standard styles of construction, including the use of concrete beams of great rigidity. With the concrete beams, however, the joints still have to be repaired, and these repairs have become very difficult.

The following brief description of a type of construction which has been suggested, is offered for criticism: First, make a simple rectangular concrete trough deep enough to take in the standard cross-tie and rail construction, allowing for a thin ballast of gravel under the ties and possibly a small tile drain. The supporting surface for the asphalt could be made comparatively thin, owing to the rigid, unyielding sub-foundation; possibly 3 in. of concrete laid just under the asphalt surface would be sufficient. It is a question whether any other type of construction can be found which would be preferable to the granite block for use along the rails, if a T-rail track is to be used. When it comes to renewals, the salvage with this construction would be practically complete, as the foundation is as good as new, and it is only necessary to renew the rails and ties as in an ordinary street on a gravel foundation.

The speaker would be glad to have an expression of opinion as to this type of construction, or suggestions of new types or modifications of existing types.

Mr. Lawton. WILLIAM H. LAWTON, M. AM. SOC. C. E. (by letter).—In providing for any future pavement, the constantly increasing use of auto-vehicles must be considered. Some time, no doubt, in the distant future, they will entirely supplant horses as a motive power. At present, however, both must be considered, and, for the use of either, the future pavement should be indestructible; it should be hard and rigid, but not noisy; it should be smooth, but not slippery, either wet or dry; and it should be easily kept clean.

The theoretical definition of a pavement is: An artificially improved roadbed, constructed of such durable material and presenting at all times such a smooth and firm surface as to facilitate street traffic of all kinds.

Street traffic is influenced greatly by the character and condition of the pavement, the width of the roadway, and whether encroached upon by street-car tracks.

All pavements are subjected to destructive action, principally by the combined forces of abrasion, crushing, and percussion, the latter, on account of the impact of horses' hoofs, being probably the most destructive. The weight of the loads and the grinding of the wheels are also large factors.

Its resistance to wear, or its durability, is the supreme test of

every pavement; and its form or shape is of small account. The durability of a pavement depends on its ability to withstand compression and concussion, as to brittleness; and grinding and polishing, as to toughness. It is also subjected to loss and change by wear and friction. Mr. Lawton.

Other important requisites are the imperviousness of the material and its ability to resist climatic conditions and changes. The pavement should also be sanitary, as to construction; and reasonable, as to cost and maintenance.

The relative durability of different pavements is measured by the amount of traffic each will stand before it becomes worn out. With regard to quality, there is at present no definite recognized standard except the general one derived from actual experience. Until some standard is adopted to determine the average life of different pavements, just conclusions can hardly be reached. Some standard, such as will measure the tons of traffic per square foot of area during a certain time, would seem to be most reasonable. The physical life of a pavement, as regards repairs or renewal, should also be considered. When a pavement is laid upon a prepared foundation, and is monolithic in form, or is composed of broken stone with or without mixtures, the requisite repairs may often be made economically for a long period by incorporating new material. When pavements are of block form, there comes a time when it is poor economy to repair or relay them.

The annual expense of pavements has been represented by formulas derived by assuming that their length of life bears a certain relation to their original cost. More study and experience, however, are needed to render some of the variable quantities constant.

Most pavements can be classed under two forms, either block or monolithic; and in the Northern States a solid substructure or foundation is absolutely necessary for each. The prevailing foundation is concrete, from 6 to 8 in. deep, and composed of Portland cement and crushed stone. This foundation is the integral part of the pavement itself, and, under ordinary circumstances, will endure for ages. Upon it is laid the wearing surface selected, which, as it becomes worn, may be renewed or may be replaced by one of another kind. This wearing surface, or pavement proper, should depend principally upon the nature of the street traffic and the character of the street, but local interests or political influences often prevail. Many paving companies maintain a special agent, who not only extols the merits of his wares, but prejudices in his favor the proper authorities or the adjoining property holders. All real-estate owners recognize thoroughly the value of a good pavement, as not only is the street improved in appearance, but all property in that vicinity is enhanced in value.

Mr. Lawton.

There are many forms of block pavements, the principal ones being natural and artificial stone, brick, asphalt, glass, iron, cobble and wood.

The weakest part of each separate pavement is its edge, which first wears away—becomes chamfered in fact—leaving all the surface joints enlarged, and every block itself becomes rounded on top, and smooth and slippery. The concussion of horses' feet is the principal cause of this injury; and if only auto-vehicles were used, the deterioration would not occur as quickly nor extend as deep.

The blocks, also, are frequently of such size and shape, with such length of joints, that the pavement provides a poor foothold for horses.

The proper way to lay pavements is to embed them in a cushion of sand upon a heavy concrete foundation. Another important feature is the composition of the filler which is run in the joints. The best filler is made up of fine gravel and a mixture composed of asphalt and coal-tar. This mixture renders the pavement less noisy, and, as it softens and expands in warm weather, it makes expansion strips unnecessary. Liquid cement or grout is sometimes used, but it tends to make the entire pavement absolutely rigid, with no chance for expansion. Cement joints are likely to be broken by heavy traffic, and the filler, not being plastic, never runs together again.

The best stone pavements are Belgian block, of trap rock, granite, and the hard sandstones.

As to the dimensions of these blocks, the opinions of engineers vary. Where horses are the motive power, the blocks should be as wide as the horse's foot. It should be long enough not to tilt, but not so short as to present a surface which is nearly all joints. As but few stone blocks are worn out by actual street traffic, they need be only deep enough to insure perfect stability. The surface dimensions of all pavements will remain a mooted question as long as street traffic continues to be by both horse and motor power.

No artificial stone pavement has yet been invented that will compare favorably with the natural stone blocks already described.

Among the monolithic pavements, the principal ones are those composed of Portland cement and of asphalts and bitumens. The wearing surface of the former consists of a layer, about 2 in. thick, of Portland cement concrete of about equal parts, mixed on the street, and incorporated in place upon the foundation already prepared. The surface is usually blocked off, by deep grooves, into squares of the desired size. This pavement is very slippery, especially in wet or frosty weather.

All the monolithic pavements deteriorate chiefly by injury from

the impact of the calks of the horses' shoes. At present, most of the best forms of pavements mentioned, except macadam, appear to be equally serviceable for traffic by horses or auto-vehicles. Upon macadam the great dust raised by autos makes travel, not only very disagreeable, but even unsanitary. Also, the suction of the pneumatic tires, whether bound with chains or covered with leather bands full of iron rivets, destroys the binder, and ravels and scatters the crushed stone. Mr. Lawton.

Sprinkling the surface with crude oil, or coating it with some preparation of tar, improves the wearing surface very much.

Owing to these defects, plain macadam paving should be considered as unlikely to be the pavement of the future.

From some form of cement or steel will probably be derived the future pavement. Experiments have been made with solid and hollow iron blocks, also hollow iron cylinders filled with concrete, and wooden blocks capped with steel plates; but none of these has yet fulfilled the requisites of a first-class pavement.

Millions of dollars are being spent every year on city pavements, many of which are imperfect or wholly experimental. Is it not policy, then, for all municipal engineers to obtain, in a thorough and systematic manner, all the reliable data in relation to the wear of traffic in classified pavements?

Can the relative comparison of one pavement with another be made in any other way?

Is not this the only scientific method by which proper data may be obtained for guidance in the construction of the perfect future pavement?

PHILIP W. HENRY, ASSOC. M. AM. SOC. C. E. (by letter).—Pavements of the present may be divided, as to origin, into two classes, mineral and vegetable, and, as to surface, into two classes, sheet and block. As cheapness and durability are characteristics of mineral as against vegetable, and as noiselessness and ease of traction are characteristics of sheet as against block, it is evident that the pavement of the future will be of mineral origin, laid in an unbroken surface. Mr. Henry.

Existing pavements of mineral origin laid in sheet form are macadam and asphalt, both of which consist of mineral particles bound together with some sort of cementing material, differing only in kind, and in quality and size of particles. No doubt the pavement of the future will consist of mineral particles of the proper quality, proper size and proper cementing material. Just what will prove to be "proper" is a matter which will now be discussed. It is understood that in this discussion only the wearing surface will be considered, as it is assumed that in any case a suitable foundation will be adopted, whether such foundation consists of Portland cement concrete or other rigid material.

Mr. Henry.

Quality of Mineral Particles.—In both macadam and asphalt pavements, while limestone and other soft stones have been used successfully in foundations, experience has proven that a hard tough stone must be used for the wearing surface. Thus trap rock, granite, or flinty limestone are preferable to the ordinary limestone, which, under traffic, is soon reduced to powder, necessitating constant repairs. For asphalt pavements, a siliceous sand is used almost exclusively, owing both to its abundance and to its wearing qualities. In some sections a shale or a calcareous sand has been used with satisfactory results where the particles are so small as to resist crushing. As a general proposition, however, it may be assumed that the pavement of the future will be composed of mineral particles of some hard, durable stone, such as quartz, trap rock or granite.

Size of Mineral Particles.—While the quality of the mineral particles may be considered as definitely settled by past experience in favor of a hard, durable stone, there is still a difference of opinion as to the proper size of these particles. It is generally conceded, however, that whether the largest particle is from 1 in. to 2 in. in diameter, as in macadam; or whether it is $\frac{1}{10}$ in. in diameter, as in asphalt pavements, the different particles, from large to small, must be graded in size so as to produce a minimum of voids. Thus, no matter what the size of the largest particle, there must be a sufficient number of fine particles to bring about that compactness and density so essential for durability. It is doubtful if this grading of particles has received much attention from those who lay ordinary macadam. This matter, however, has received most careful study and attention from those who lay that form of bituminous macadam called "bitulithic," which was introduced into America about five years ago, and since then has been laid in many cities throughout the United States and Canada. No doubt the success which this pavement has had over other bituminous macadams is largely due to the great care observed in proportioning the different sizes of mineral particles entering into its composition, beginning with 1 in. or $1\frac{1}{2}$ in. as the largest size, and continuing in definite proportions down to $\frac{1}{200}$ in. and less in diameter. By both theory and experience it has been found that certain definite proportions of different-sized grains are essential to produce the best results.

When the asphalt pavement, as known in America, was introduced, some thirty years ago, the necessity of proper sand grading was well appreciated, but in the effort to extend the business, demanding so much time and energy, the technical side was for a time neglected.

In the early days of the industry, pavements laid in different

Mr. Henry.

cities, with apparently the same proportions of sand and asphalt cement, gave very different results; and upon investigation it was shown that this difference was largely due to variation in the sand grading. At the present time it is well understood that, for the best results under heavy traffic, there should be a certain proportion of mineral particles $\frac{1}{10}$ in. in diameter, a certain proportion $\frac{1}{20}$ in. in diameter, and so on, down to impalpable powder. As this definite sand grading is not generally found in any one deposit, it is customary to mix sands from different deposits. As very few sands carry much 200-mesh material, it is customary to supply this very fine material in the shape of ground limestone or Portland cement.

In macadam the largest particle is from 1 in. to 2 in. in diameter, and in asphalt pavements the largest particle is $\frac{1}{10}$ in. in diameter. In the pavement of the future it is likely that both these gradings will be used, the coarser grading on streets of light traffic where there is little danger of crushing, and the finer grading on streets of heavy traffic where compactness and uniformity are essential.

Kind of Cementing Material.—In ordinary macadam dependence is placed upon the stone or gravel itself for cementing material. Some limestones and gravels contain a certain amount of cementing material, and when properly watered and rolled the mineral particles will be tightly held together. Under heavy traffic, however, and especially since the introduction of the automobile, the finer particles in the macadam are soon separated and converted into dust. To overcome this difficulty, there have been introduced, for sprinkling macadam, various compounds, such as mixtures of water and calcium chloride, water and saponified oil, special crude oils, special products of coal tar, etc. All these, however, are useful only under the lightest form of traffic, and have as their chief recommendations the cheapness and ease with which they can be applied. This sprinkling is effectual only on the upper layer of particles, as the various solutions have comparatively little penetrating effect.

In order to get the best results it is necessary to coat each mineral particle with some kind of a cementing material, and to lay this mixture to a depth of from $1\frac{1}{2}$ to 3 in., depending upon the amount of traffic. As cementing materials, both Portland cement and bituminous cement have been used. While Portland cement has been tried in various cities for a number of years, the results under heavy traffic have not been satisfactory, owing chiefly to the rigidity of the wearing surface, which would not stand the blows of traffic. Under light traffic, however, with proper attention to the grading of mineral particles, as above mentioned, there is, perhaps,

Mr. Henry. a future for Portland cement owing to its cheapness as compared with bituminous cement.

For many years, both in America and in Europe, bituminous cement in the form of coal tar has been used in the paving industry. Such pavements have been known as "tar macadam," "coal-tar pavements," "concrete pavements," etc. Owing, however, to its lack of uniformity and its volatility under the rays of the sun, coal-tar was practically abandoned upon the introduction of asphalt pavements. Within the past five years coal-tar has again been used extensively in bituminous macadam or bitulithic pavements. Whether a better and more uniform grade of coal-tar is now being produced than was the case thirty years ago is a question which time alone can determine. Owing to its cheapness, as compared with asphalt, coal-tar will doubtless be used in the future, as it is to-day, on streets of light traffic, but, owing to its susceptibility to changes of temperature and its more volatile nature, it is doubtful if it will be used for pavements subjected to heavy traffic.

The word, "asphalt," first applied to pavements was the "asphalte comprimé," known in America as "rock asphalt," laid in Paris in 1854. This was a limestone impregnated with bitumen, found in Switzerland, and later in France, Germany, Sicily, and other parts of Europe. To this day practically all the asphalt pavements of Europe are rock asphalt. On the other hand, in America there are very few rock asphalt pavements, due largely to the high cost of European rock asphalts, and to the inferior quality of those of America.

Practically all the asphalt pavements of America are composed of mineral particles cemented together with "asphalt cement." This mixture was devised by Edward J. De Smedt, a Belgian chemist, who came to America in 1861, and took out his first patents in 1870. The "asphalt cement" was composed of Trinidad asphalt, fluxed to the proper consistency with petroleum residuum; and the mineral particles were composed of sand and powdered carbonate of lime. This is still the combination used in many of the asphalt pavements of the present day. For twenty years or more Trinidad asphalt was used exclusively as the cementing material, but in 1893 an asphalt, occurring in Venezuela about 100 miles from the Trinidad deposit, known as Bermudez asphalt, was introduced, and has been used extensively ever since in the paving trade.

During the past six or eight years, in addition to natural asphalts, such as Trinidad, Bermudez, Cuban, Maracaibo, etc., there have been introduced bitumens manufactured from petroleums having an asphaltic base. These bitumens are known as "oil asphalts," "artificial asphalts," or "residual pitches." Just what part these particular products of petroleum will play in the asphalt pavements of the future, is a question which only time can determine.

Mr. Henry.

There is no doubt that the natural asphalts are also products of petroleum, resulting from Nature's process of distillation. The crude petroleum has been forced to the surface by pressure from below, flowing down watercourses, as in Mexico; spreading over swamps, as in Venezuela; or filling the crater of an extinct mud volcano, as in Trinidad. Nature's distilling process, extending as it does for years, at the temperature of the sun, combined with the effect of the winds and rains, produces an asphalt well adapted for use in pavements which are exposed to all sorts of climatic conditions.

As there have been advances in the proper grading of mineral particles, so there have been advances in the proper consistency and proportions of asphalt cement. Various fluxes have been used for softening the natural asphalts, all of which are too hard in themselves. With some asphalts, results are apparently the same, whether the flux is made from the paraffine petroleums of the East, the semi-asphaltic petroleums of Texas and Kansas, or the asphaltic petroleums of California. With other asphalts the California fluxes give the best results; but, whatever the flux, it is generally considered that a certain consistency (known as penetration) of asphalt cement is desirable for certain conditions of traffic and climate, and well-recognized standards have been established.

There is still some difference of opinion as to the exact proportion of asphalt cement to be used in the paving mixture. This depends so much upon the kind of sand and dust, that no definite rule can be laid down. No doubt the future will bring about the solution of this problem along with many others.

Conclusion.—No doubt the development of the future will be in the line of various grades of macadam and asphalt, depending chiefly upon the kind and amount of traffic. That macadam is already the standard, for country roads and suburban districts all over the world, is well known, and no doubt an improved form of macadam will remain the standard of the future for this class of roadways. Like macadam, asphalt has become a standard form of pavement, especially for cities.

In 1876 Congress appointed a Commission, composed of the architect of the Capitol and two officers of the Engineer Corps, to select the best kind of pavement for Pennsylvania Avenue, Washington, to replace the wooden blocks laid only a few years previously. In all, there were more than forty proposals, representing all sorts of paving materials. Out of all these proposals, the Commission selected rock asphalt for one-third of the Avenue, and the "artificial siliceous" asphalt pavement (the ordinary asphalt pavement of to-day) for the other two-thirds. As up to that time there had been laid only 20 000 sq. yd. of the "artificial siliceous" as-

Mr. Henry. phalt pavement, the oldest less than five years, the Commission may be said to have had the courage of its convictions. That its judgment was correct is evident from the fact that in 1907 when the repaving of Pennsylvania Avenue again came up for decision, no other material for the entire Avenue was considered than that same variety of asphalt pavement, which, thirty-one years before, was selected for paving two-thirds of the Avenue.

Since that original selection, more than 60 000 000 sq. yd. of asphalt pavement have been laid in the United States and Canada, of which 18 000 000 sq. yd. have been laid in the past three years.

That other forms of pavement, such as stone blocks, brick, wood, etc., will remain in use, under conditions best adapted to these particular materials, is conceded, but the great development of the future will be along the line of macadam and asphalt, both of which have passed the experimental stage, and in both of which there are still greater possibilities.

Mr. Bienenfeld B. BIENENFELD, M. AM. SOC. C. E. (by letter).—The rapid development and increasing use of the horseless carriage, or automobile, point to a largely extended and constantly increasing demand for smooth pavements. For many years, however, horses and other draft animals will be in evidence upon our streets, and provision must be made in the future, as at present, to facilitate the tractive efforts of these beasts of burden. On grades, and where heavy loads are to be hauled by animals, stone and brick, and possibly wood, will continue in use; but, as paving materials, these three substances possess many patent disadvantages, and their use will always be restricted to cases where the smoother and more ideal pavement is undesirable or unattainable.

The tendency toward the building of smooth, impervious, noiseless, dustless, monolithic, sheet-pavements is therefore ever on the increase. With the lights now before us, there is no reason to apprehend a falling off in that tendency. This will necessitate a large and reasonably cheap supply of asphalt. The asphalt fields of Europe, the West Indies, and South America, will continue to yield a reasonably large and cheap supply. Since their first exploitation in 1893, the asphalt-oil fields of California have given to the world an additional supply of asphalt; and it is possible that the asphalt-oil fields of Mexico may, in the future, be counted on as an additional source of supply.

As first made in California, the so-called oil-asphalt, produced by inexperienced manufacturers and laid by unskilled pavers, gave results which were far from acceptable; but, after fourteen years of experience in manufacture and laying, it may now be said that paving asphalt is being, and can be, produced from California oil, which is equal, if not superior, to any asphalt produced from any

other source. It is, of course, the custom and habit of persons representing special interests still to condemn and to "damn with faint praise," this so-called "artificial" asphalt. But as "the proof of the pudding is the eating," so the proof of this asphalt is its wearing, and the constantly and rapidly increasing demand for it. It has found its way into successful paving use in nearly all the large cities of the United States and Canada. Mr. Bienenfeld

During 1905, the latest year for which any statistical data are available, there were produced in California 50 000 short tons of oil-asphalt, which is the equivalent of 87 000 tons of refined Trinidad asphalt. In the fiscal year ending June 30th, 1905, the total asphalt imports into the United States from all foreign sources were 157 000 tons of crude, dried, "advanced," and rock asphalts. These crude materials contain from 20 to 70% of bitumen, whereas the California material contains more than 99% of bitumen. Allowing an average of 50% of bitumen in the imported asphalts, which is an excessive estimate, their total bitumen paving value would be 78 500 tons, as against the 50 000 tons of the California production. It is evident, therefore, that California, according to the latest data, is supplying about 40% of the asphalt requirements of the United States.

The oil production of California, which is to-day larger than that of any other State in the Union, is still increasing, through the discovery of new fields and the extension of the older ones; and there is every reason to believe that its asphalt production will be amply able to meet all demands that may arise in the next decade or two. In 1905, California produced 34 000 000 bbl. of oil, having an asphalt content of about 1 250 000 tons of pure, paving bitumen, of which only 50 000 tons, or 4%, were actually manufactured to meet current demands, the remaining possible 96% having been consumed as fuel.

The Republic of Mexico is at present producing asphaltic-oil, and may in the future enter the ranks as an important asphalt-producer, thus adding to the sources of asphalt supply. It is to be hoped that the producers of Mexican asphalt will profit by the early experiences and mistakes of the California manufacturers; and that they will allow no material to leave their refineries which is not in all respects acceptable and suitable for paving purposes. Care and technical skill are requisite; without these, the results are likely to be very unsatisfactory and possibly disastrous. For some time to come, however, all the Mexican oil production will probably be required to meet the fuel demands of that republic; and some years may elapse before Mexico can become an important asphalt producer. Its oil resources are at present largely undeveloped; and its asphalt possibilities are therefore as yet unknown.

Mr. Bienenfeld

The oil resources of other and more distant portions of the globe are still in reserve, unexploited. It is likely that some of them contain true asphaltic oil, similar to, if not identical with, the asphalt-oils of California. The asphalt resources of the West Indies and of South America are by no means exhausted. There is in sight, therefore, for future use, an ample supply of acceptable asphalt; and all the indications and tendencies of to-day make for a larger use of this paving material of the present in the construction of the pavements of the future.

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PAPERS AND DISCUSSIONS.

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ELECTRIC RAILWAYS.

An Informal Discussion at the Annual Convention, July 10th, 1907.*

SUBJECT FOR DISCUSSION:

"(*a*) What are the factors which determine the maximum economical grade for electric railways?

"(*b*) In establishing direct lines with heavy grades, under what conditions will it be found practicable to use electric locomotives and gas-engine generating stations, rather than traction by steam locomotives?"

BY MESSRS. W. W. FOLLETT AND J. T. NOBLE ANDERSON.

W. W. FOLLETT, M. AM. SOC. C. E.—Referring to the electrification of Soldier's Summit hill on the Rio Grande Western Railroad, in Utah, to which reference has been made, some twelve years ago, the speaker had a long conversation with General William J. Palmer, then President and principal owner of the Rio Grande Western, concerning the use of electrical power on this hill. After a thorough consideration of the subject, the conclusion was reached that the traffic was not heavy enough to stand the expense of electrification, that is, that the train movements were not frequent enough. General Palmer dropped the matter and never took it up again. Mr. Follett.

When trains are handled by electrical power, there must be a large volume of traffic, else the interest on the capitalization of the outfit, cost of keeping the lines charged all the time, including the loss of power by induction, and the expense of electrical repairs, will be so

* Continued from August, 1907, *Proceedings*.

Mr. Follett. great as to outweigh the advantages. Of course, where train movements are frequent, there is probably no question as to the economy and advantages which follow the use of electricity.

Mr. Anderson J. T. NOBLE ANDERSON, M. AM. SOC. C. E.—The speaker would mention an electric railway that is being constructed in New Zealand. The west coast of New Zealand is separated from the east coast by a long range of snow-clad mountains, in a manner somewhat similar, except on a smaller scale, to the way in which the Rockies separate the east and west coasts of the United States.

Some 12 or 14 years ago a British company, the Midland Railway Company, was organized and obtained large concessions of land for the construction of a railway to connect the coasts of New Zealand. After struggling with the problem for about eight years, the company finally abandoned the work, and the Government of New Zealand is now constructing the connection. The work as now designed, however, is quite different from what it was originally. The chief reason for alteration was that, owing to the fact that much steeper grades can now be used, the ruling grade being 1 in 25, a single-track tunnel about 6 miles long with heavy drainage grades has not been feared. The tunnel runs under a mountain ridge between 4 000 and 5 000 ft. above the level of the line that passes under it; and the rise in the tunnel is steeper, it is thought, than any of the Alpine tunnels between Switzerland and Italy. Of course, with electric plant, etc., there is no difficulty, and in that mountainous country, with the Bulwer River flowing past, there is no lack of water power. All the railways of New Zealand will eventually be run by electricity.

One other point: in his practice in New Zealand the speaker has found it expedient to use Diesel oil engines. These engines are used in the various cities in Great Britain and Europe for tramway traffic. All the tramways in Moscow are also run by these engines, but as yet they do not seem to be much known in the United States. They are known to the scientific men, however, and have been written about by Lord Kelvin. Mechanical engineers appreciate what the Diesel engine is, since it can be run with crude oil; it is an engine that requires only one attendant, and, as compared with an ordinary gas engine, has the advantage that it can be run at any desired speed. It can also be run at about a quarter or half its rated capacity and practically as good economy results as when it is run under full load. For tramway work, running with very variable load, is a very important factor, and an engine which can be run under one-third its capacity as economically as under a full load is of importance to everybody. Diesel engines are used for the whole 24 hours of the day at a cost which, including interest on the plant, amounts, in England, to about £8 ($40) per h.p. per annum; many of them, if located where crude oil is cheap, give even better results.

Mr. Anderson.

The speaker would like to say more about these engines, because the results obtained with them have justified the opinion he had formed from reports from such men as Lord Kelvin, and because they have exceeded all his expectations. In two particular cases where he used them, the speaker, owing to New Zealand being so far from the manufacturing point, took the precaution to have very clear specifications, making the manufacturers subject to heavy damages if the engines did not come up to the guaranty, and in both cases they are doing better than was called for by the guaranty.

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COMPARISON OF RAINFALL AND RUN-OFF IN THE NORTHEASTERN UNITED STATES.

Discussion.*

BY MESSRS. E. C. MURPHY, CHARLES A. HOLDEN, H. C. FRANKENFIELD AND ALFRED J. HENRY, AND THADDEUS MERRIMAN.

Mr. Murphy.

E. C. MURPHY, ASSOC. M. AM. SOC. C. E. (by letter).—The writer believes that the data available for computing run-off from precipitation will not justify the use of this method for estimating stream flow, even in the eastern part of the United States, where the number of precipitation stations per unit area is largest and the records longest. His opinion is based on measurements of run-off and a study of the corresponding precipitation data. He has observed large floods on streams, that the precipitation data do not indicate, because the stations were too few; he has also observed annual run-off larger than the observed annual precipitation, due to the stations not being properly located with respect to altitude. He believes that writers on this subject do not, as a rule, treat it fairly. While they admit that the available data are unsatisfactory at best—on account of lack of funds for its collection, and lack of data for computing the effect of some of the quantities upon which run-off depends—nevertheless, they draw conclusions from their results as if the data were good and complete, and intimate that the results obtained by this method are as good, if not better, than those obtained by gauging. They subject their data, such

* This discussion (of the paper by John C. Hoyt, Assoc. M. Am. Soc. C. E., printed in *Proceedings* for May, 1907), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

as they are, to various mathematical processes which have little, if any, experimental basis, and in some mysterious way much value is imparted to them. To illustrate: a recent user of this method, when he found the measured monthly precipitation at any station more than twice the mean for that month, substituted the mean for the observed quantity. That is, when perchance one of the few precipitation stations was near the center of a storm area, and its record was approximately the rainfall corresponding to the measured run-off, he threw away the record and used in its place a quantity less than half the observed quantity. By this and similar processes he finally obtained what he called "deduced mean annual dependable precipitation." His computed run-off is so reliable that "stream gaugings were only used as a guide." Mr. Murphy.

Run-off is a resultant quantity; its value depends upon several quantities or factors. It can be obtained directly by measurement of the flow of the streams, or it can be computed from the measurements and proper combination of the quantities upon which it depends. Precipitation, while the most important, is only one of these factors; temperature, wind velocity, barometric pressure, surface and ground storage, shape and extent, inclination and character of water-shed, extent of forest and cultivated area, are other factors. This is the formidable array of quantities which the user of this method must properly reckon with in order to get a reasonably accurate estimate of run-off.

Let us see with what accuracy precipitation on a drainage basin is measured. It is admitted by all that precipitation is an erratic phenomenon; it does not follow any known law; it cannot be obtained by any mathematical process, and the only way to obtain its accurate value is by measurement or observation. The monthly precipitation at two stations only a few miles apart may differ more than 25 per cent. It varies in irregular cycles, but this knowledge does not help in the least in supplying missing data. It is seen to depend on elevation, topography and direction of the prevailing wind, but there are not sufficient data to enable the effect of these conditions to be computed with reasonable accuracy.

A measurement of rainfall is subject to two errors from air-currents, which may amount to 25% of the catch. Snow measurements are subject to larger error than rainfall measurements. A rain-gauge has a diameter of only 8 in. and shows the rain falling on an area of less than 0.35 sq. ft. What confidence can be placed in the precipitation on a water-shed computed from available data? Take, for example, the Susquehanna River water-shed, above Williamsport, Pa., mentioned by the author. There are eight precipitation stations in an area of 5 640 sq. miles—one station to 725 sq. miles. The precipitation on 725 sq. miles is computed from that on less than half a square

Mr. Murphy. foot. This station is located of necessity at a convenient place, each measurement is subject to an error of 25% of the catch, and the law of change between stations is not known. The engineer has very little confidence in such data, and will only use it for rough preliminary estimates.

Wind movement is neglected entirely. From evaporation measurements it is known that the loss from a body of water increases as rapidly as the wind velocity increases. How is it possible to get such reliable estimates of run-off by this method, when so important a quantity as wind movement is neglected?

In striking contrast with all this uncertainty from lack of data is the simple direct method of obtaining run-off by gauging the streams. This method gives the run-off for each month and day, as well as the annual run-off. If a meteorological station were maintained in each township (36 sq. miles) where not only precipitation, temperature, wind velocity, and atmospheric pressure, but all the other quantities upon which run-off depends, were measured, data would then be available for a reasonably accurate estimate of run-off from rainfall. It would be folly, however, to spend so large a sum for run-off data, when the run-off can be measured for a much less sum.

In the early days of the settlement of this country, there was a great demand for meteorological data, mainly for agricultural purposes, and no demand for run-off data; at the present time there is a great demand in many parts of the country for run-off data. Stream gauging alone can satisfy this demand.

The writer does not wish to convey the idea that the method of computing run-off from precipitation should never be used. It may be used with profit in some sections of the country in connection with stream gauging. If, for example, the flow of a stream at a given place is known from stream gaugings for, say, three years, and the precipitation over the basin is also known, with a reasonable accuracy, for these same three years and, say, the preceding five years, then an approximate estimate of the annual run-off for the latter period may be computed from the precipitation of that period, together with a comparison of precipitation and run-off for the former period when the gaugings were made. In other words, this method may be used to supplement stream-gauging records, but to compute run-off from meteorological data without gaugings appears, to the writer, to be a waste of time.

Mr. Holden. CHARLES A. HOLDEN, ASSOC. AM. SOC. C. E. (by letter).—The writer is in hearty accord with the efforts of Mr. Hoyt to bring about the estimation of available water supply through the use of run-off data instead of the comparatively uncertain precipitation data.

Precipitation data must always give a very imperfect record since, of necessity, observation stations are situated only at infrequent in-

tervals and at varying positions in elevation. All are familiar with the phenomenon of heavy rain in one section and little or none within 2 or 3 miles or even less. There are also many other factors to be considered, account for which can be made but imperfectly. The quantity of water running off, as the author points out, will depend upon the stage of the ground water. It, as well as the ground water, will depend upon whether the ground is or is not frozen, the character of the soil, the amount of wooded and tillage area, and the topographic and geologic configuration of the tract under discussion. Mr. Holden.

The case in point is well illustrated by Table 2* and is even better shown by diagrams which the writer prepared in connection with his work as Resident Hydrographer at the Orford Station in 1900-04. On these diagrams the points, in different years, for maximum and minimum rainfall are not in the same relation to the points for maximum and minimum run-off in the table above referred to.

The order in amount of precipitation for January is 1902-03, 1904-05, 1903-04, 1901-02, 1900-01.

The order for amount of run-off in January is 1901-02, 1902-03, 1900-01, 1904-05, 1903-04.

The order for amount of run-off in February is 1902-03, 1900-01, 1901-02, 1903-04, 1904-05.

The order in amount of precipitation for July is 1904-05, 1900-01, 1902-03, 1901-02, 1903-04.

The order for amount of run-off in July is 1901-02, 1904-05, 1900-01, 1902-03, 1903-04.

The order for amount of run-off in August is 1901-02, 1900-01, 1904-05, 1902-03, 1903-04.

For the entire periods chosen the order in amount of precipitation is 1901-02, 1900-01, 1903-04, 1902-03, 1904-05, while the order for run-off is 1901-02, 1900-01, 1902-03, 1904-05, 1903-04.

The run-off in percentage of precipitation for the periods shown varies more than 20% from the mean, and the largest is nearly one and one-half times the smallest.

The valuable work in stream gauging, undertaken by the United States Geological Survey, ought not to be curtailed in efficiency by reason of lack of funds for the prosecution of the work.

It is also of great importance that further investigations should be made to determine better constants for guidance in gauging rivers through the ice, and that greater effort should be made either to take the gauge heights to the water, or else to obtain more frequently the thickness of the ice under the gauging point.

MESSRS. H. C. FRANKENFIELD† and ALFRED J. HENRY† (by letter). —At the regular stations of the United States Weather Bureau in Messrs. Frankenfield and Henry.

* *Proceedings*, Am. Soc. C. E., May, 1907, p. 463.

† Asst. Chfs., Forecast Div., U. S. Weather Bureau.

Messrs. Frankenfield and Henry.

large cities rain gauges are generally exposed on roofs of office buildings. These exposures, while not satisfactory in all respects, are the best that can be had under the circumstances.

In winter, when roof exposures are most objectionable, the snowfall is measured in the open at some distance from buildings or other obstructions, and at a point where drifting is least pronounced.

The rain gauges at co-operative stations of the Bureau are generally located on the ground, 40 or 50 ft. distant from surrounding objects, and the exposures are considered good. The total precipitation from both classes of stations, regular and co-operative, are platted each month on large scale maps of the United States. By this means it is possible to discover improbable values and incorrect reports. This method also affords a means of comparison between roof and ground exposures, since there is generally one or more ground-exposed gauges near Weather Bureau stations in large cities. The monthly charts of precipitation, on which the rainfall values from both classes of exposure are spread indiscriminately, show no differences of importance. The natural variation in the rainfall between any two places within a short distance of each other is much greater than any discrepancy that may appear between the catch of a roof-gauge and that of a ground-gauge.

The need of rainfall stations at high altitudes is fully realized by the Weather Bureau. A few years ago an attempt was made to increase the number of high-altitude stations through co-operation with the Forestry Service of the Department of Agriculture, but the plan failed. The Bureau now maintains, on the head-waters of some rivers, a number of rainfall stations at an average expense of $100 per annum for each station. The greater majority of its rainfall stations, however, are operated by private persons who do the work without compensation; the field of observation for this class of persons is naturally limited to the habited areas, and to those which almost without exception are found in the valleys and low levels. In the Far West and at great altitudes, the question is further complicated by the extreme difficulty of measuring precipitation when it is mostly in the form of snow and badly drifted by the winds. During the winter of 1906-07, a special form of snow-gauge was devised and placed on the summit of the Sierra Nevada and at other stations. It is expected that the experience gained by the use of this instrument will be useful in solving the instrumental problem. The great desideratum, however, is, and always will be, persons to do the work at remote places and in high altitudes. An increase in the number of high-level stations is included in a project for the reorganization of Weather Bureau work now under consideration.

In determining the mean precipitation for the several drainage basins, the author takes the average of the whole number of rainfall

Messrs. Frankenfield and Henry.

stations in each basin. For relatively small areas this plan works well, and the results are probably as near the truth as can be obtained with the number of rainfall stations available. The greater the number of well placed stations, the greater will be the accuracy of the district means.

The precipitation during the cold months is more evenly distributed than that of the warm months, and, therefore, the means will be more dependable than those of the warm months. Owing to the very unequal distribution of precipitation in summer within quite limited areas, a large quantity of water may be precipitated over the headwaters of a stream, and yet none will be caught in any rain-gauge in the district. It is not advisable to draw hard and fast conclusions from either short periods of time or for small areas, but an attempt should be made to follow each and every individual case of heavy rain and to note its effect on the flow of the stream for all the varying conditions of soil and slope in the drainage area. As the author has pointed out, the run-off of one month may be almost wholly controlled by the rainfall of a previous month. It would be interesting to know how much time may elapse between the initial and the concluding effect of a heavy fall of rain on the drainage below; in other words, to note how long, whether one, two, or three months, a single heavy rain or several days of continued heavy rains will perceptibly affect the run-off of the stream below, and thus determine the general characteristics of each drainage area.

It is obvious that the manner in which the rain falls, whether as a steady rain of moderate intensity or as a heavy dash of great intensity, is of much importance in determining the relation between rainfall and run-off. In collecting the information contained in his paper, the author has performed a valuable service. It is hoped that the work may be carried on until at least 30 years' data have been accumulated, since there is a possibility that faulty conclusions may be drawn when the subject is considered in the light of a few years' observations only.

Mr. Merriman.

THADDEUS MERRIMAN, JUN. AM. SOC. C. E.—The author in this paper has brought together and digested in an admirable manner some of the results of the work done during the past ten years or more by the United States Geological Survey. Such an extensive compilation and comparative study of these results has, the speaker believes, been nowhere else attempted.

The author confines his discussion to nine of the larger streams in the northeastern section of this country and analyzes the stream flow past fourteen stations situated at different points on these streams. From the results of these studies, he draws the general conclusion that the annual run-off from any stream in this section of the country can be predicted from the run-off data which are now available. The speaker

Mr. Merriman. believes that this conclusion is so broad that, even if the data on which it is based were most perfect, it could not be justified. Every stream is a law unto itself, both on account of the fact that the amount of rain which falls upon it differs from that which falls upon its immediate neighbor, and also on account of its physical characteristics, most important among which are its altitude above sea-level, its mean annual temperature, and last, but not least, its slope or steepness. All these factors combined may influence the run-off to such an extent that it is not unusual to find two streams which are within a comparatively short distance of each other and which, to all outward appearances, have the same physical characteristics; yet the yearly run-off of these streams will differ by more than 25 per cent. This is true as between the Tohickon and the Neshaminy Creeks in Pennsylvania, the Esopus, the Catskill and the East and West Canada Creeks in New York. The author's contention may be true when applied to streams having drainage areas of 5 000 or 6 000 sq. miles. On a stream of this size, the causes of difference enumerated by the speaker will average up to such an extent that run-off data may be safely used for purposes of estimating. Such large streams, however, are few; most studies and estimates are made on smaller streams, each of which has its own characteristics and must, therefore, be studied by itself. The speaker submits that the laws which govern the flow of a large stream are not applicable to the flow of a smaller stream, even if the latter be a tributary of the former.

The results obtained by the author indicate that the run-off from the streams studied is somewhat greater than has heretofore been supposed. For instance, the run-off from the Housatonic River above Gaylordsville, Conn., is shown to be 62%, while it is known that the Croton River, on the same average rainfall, will yield but 48%, this too in spite of the fact that the water-shed of the Housatonic is nearly three times as great as that of the Croton. Again, the percentage of run-off, as shown for the James and the Roanoke Rivers, approaches very nearly to that of the Sudbury, notwithstanding that the rainfall on the Sudbury is greater than on either of the other streams, and that it is situated in a considerably colder climate. Again, if the run-off from the Pequannock is compared with that from the Housatonic, as given by the author, it is found to be roughly 5% less, and this, too, from a water-shed which is far steeper, and on which the rainfall is materially greater.

The gaugings on all the streams discussed by the author were made by the United States Geological Survey by current-meter methods, whereas those on the Sudbury, Croton and Pequannock are the results of other methods of measurement. The precision of the results deduced from any series of observations depends on the accuracy of those observations, and it is to be regretted, therefore, that the author

has not indicated his opinion of the value of the data used in his discussion. Mr. Merriman.

The speaker is well aware that the methods used in the measurement of stream flow are approximate only. The unknown factors and changeable conditions which enter into them are so many that they have not as yet been co-ordinated. Practically all the stream-gauging work of the United States Geological Survey has been done by the current-meter method. The instrument used is the small Price meter, which is occasionally rated in still water. Gaugings are made from time to time at the stations where the discharge is to be measured, and, from these gaugings, a discharge curve for varying gauge heights is constructed. The gauge is then read, to the nearest half-tenth of a foot, twice daily by an observer who lives in the vicinity of the station. Most stations are located on bridges, and, at many of them, particularly across the larger streams, there are one or more piers in the river.

The accuracy of the determination of the yearly discharge of a stream measured in such a manner is dependent both on the accuracy of the measurements from which the discharge curve is determined and also on the daily observations of the gauge height; of these two main conditions that which is perhaps most likely to be in error is the former. In the readings of the daily gauge heights it is probable there will be as many plus as minus errors, and that, consequently, errors due to this cause will balance each other.

The accuracy of the method is, therefore, almost entirely, if all other conditions are the same, dependent on the accuracy of the determinations of the discharge curve, if no account be taken of the unfortunate location of gauging stations on bridges which have piers in the river and where the hydraulic conditions, consequently, are much disturbed.

The current meter of the Price type with which the discharge measurements are made is usually suspended by a cable, and the velocities for each section determined by the point method holding the meter at the six-tenths depth. This meter is, the speaker believes, not well adapted to the measurement of water velocities which exceed 2 ft. per sec., in that the results given are too high, and also for the following reasons:

(*a*).—The meter is usually rated in still water where all particles of the water impinge on it in parallel lines. In flowing water, therefore, where the particles move in many different directions, the meter will, since it is constructed to be more sensitive in one direction than in the other, record a velocity which is higher than the mean velocity at the point where the meter is held.

(*b*).—The meter will respond to a current which impinges on it in any horizontal direction and, consequently, will record the velocity at the point where it is held, no matter whether the direction of the

Mr. Merriman.

current is at right angles to the cross-section where the discharge is being measured or not.

(*c*).—The meter has inertia and, therefore, will not immediately respond to a slackening of the current. This is also true as the result of its mechanical form, and, consequently, the velocity it records is greater than the mean velocity at the point where it is held on account of the pulsation of the moving water.

(*d*).—The meter, when suspended by a cable, swings back and forth like a pendulum, thus increasing the effect of the pulsations in the current.

In view of the differences between the results of the gaugings set forth in this paper, when compared with other and reliable long-term gaugings on other streams, and after having made careful allowances for the differences due to variable conditions on the water-sheds themselves, the speaker is of the opinion that there is sufficient evidence to indicate that the results for the run-off shown in this paper are uniformly too large, and that the discrepancy is approximately 10 per cent.

He believes that this excess in the yearly totals is largely due to the difficulty of measuring flood discharges with a current meter, and, since in an ordinary year considerably more than 60% of the total flow occurs at high or flood stages of the river, it becomes evident that a method to determine successfully the total yearly flow of a stream must first accurately measure the volume of water carried by a river during its high stages.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

CHARLES BLACKWELL, M. Am. Soc. C. E.*

DIED DECEMBER 29TH, 1906.

Charles Blackwell was born at Devizes, Wiltshire, England, on February 4th, 1843. He was the eldest son of Thomas Evans Blackwell, the first Vice-President and General Manager of the Grand Trunk Railway System, and came to Canada with his father in 1857. He was descended from a family of engineers, his grandfather, Thomas Blackwell, having built several stone bridges over the river Avon near his native town of Devizes, Wiltshire. His father, Thomas Evans Blackwell, was the first Hydraulic Engineer in England, and built the Kennet and Avon Canal. Mr. Blackwell attended the High School and McGill College at Montreal.

In 1860 he entered the service of the Grand Trunk Railway Company, where he remained until 1869, being employed principally in the Motive Power Department. From 1869 to 1876 he was engaged upon the location and construction of the Intercolonial Railway, having charge of a 22-mile section for three years, and of a 74-mile section for two years of this time. During this latter period he had supervision of the equipment and of the erection of the machinery in the principal repair shops at Moncton, New Brunswick.

During 1876 and 1877 he was Resident Engineer in charge of the completion of 45 miles of the Quebec, Montreal, Ottawa and Occidental Railway. From 1877 to 1879 he had charge, as Resident Engineer, of the improvement and construction of the Quebec. Central Railway. In 1879 he was appointed Mechanical Engineer of the Dominion Department of Railways and Canals, and had prepared, under his direction, detailed specifications and drawings for the construction of all kinds of rolling stock required for the Canadian Pacific Railway, and also specifications and drawings for the water service on that road.

Upon the completion of construction on the Canadian Pacific Railway, in 1881, and the turning over of the line to the operating company, Mr. Blackwell went to Roanoke, Virginia, as Superintendent of Motive Power of the Norfolk and Western and the Shenandoah Valley Railroads. The Roanoke shops were constructed and equipped according to the plans and specifications prepared by him. The building and equipping of these shops occurred at the time when modern shop practice was just developing, when heavier engines and cars were just

* Memoir prepared by Walter S. Newhall, Esq.

arriving, and when the locomotive and car equipment of it was only dimly foreshadowed, but dreamed of; and yet the Roanoke shops, while they have been extended, remain—as far as their particular buildings are concerned—as Mr. Blackwell planned them, and are well known for their capacity and economical efficiency under present conditions.

Mr. Blackwell left the Norfolk and Western Railroad in 1885, and was engaged on the Union Pacific Railroad for three years, during one year of which he was Manager of the Montana Division.

In 1888 he went to the Central of Georgia Railway as Engineer of the Machinery Department, and remained with that company at Savannah, Georgia, for two years. On account of ill-health he had to come north again, and from 1891 to 1897 was not engaged in railway work; four years of this time he was with the Schoenberger Steel Company, his headquarters being in Pittsburg.

He again entered railroad service at Toledo in 1897 as a special Mechanical and Civil Engineer in the office of the Receivers of the Wheeling and Lake Erie Railroad, remaining with this company after its reorganization, and becoming Principal Assistant Engineer subsequent to August, 1900. During the time he was engaged on the Wheeling and Lake Erie Railroad he made many investigations and reports on that and other properties. In 1903 Mr. Blackwell was tendered the position of Special Assistant to the Chief Engineer of the Wabash Railroad, and entered the service of that company on January 1st, 1904, where he remained for two years.

During the last six years of Mr. Blackwell's life the writer of this memoir was fortunate in knowing him intimately, both socially and professionally, and formed a strong attachment for him. Accurate, methodical, resourceful, with a keen mind for detail and a fund of information acquired by long and varied experience, both as a Mechanical and Civil Engineer, he was especially well adapted to fill the confidential positions which he occupied during the last eight or ten years of his life.

Loyal, kind, and generous, a student of the times, both past and present, he was a charming companion. Born a gentleman, he remained one to the end.

During the last year of his life his health failed rapidly, and he died of Bright's disease, at Cincinnati, on December 29th, 1906.

On December 27th, 1878, Mr. Blackwell was married to Emily, only daughter of Edward B. Chandler, Esq., Barrister, of The Grange, Moncton, New Brunswick, and granddaughter of The Honorable Edward Barron Chandler, Commissioner of Railways, and Governor of the Province of New Brunswick. Mrs. Blackwell and three sons, Thomas Everette, Hubert Charles, and John Buckland, survive him.

Charles Blackwell was elected a Member of the American Society

of Civil Engineers on September 7th, 1881. He was also an Associate Member of The Institution of Civil Engineers of Great Britain; an Honorary Member of the American Railway Master Mechanics Association; and a Member of the Master Car Builders' Association.

SYLVANUS THAYER ABERT, M. Am. Soc. C. E.*

DIED AUGUST 11TH, 1903.

Sylvanus Thayer Abert was born on July 22d, 1828. He was a son of the late John James Abert,† Hon. M. Am. Soc. C. E., Chief of Topographical Engineers, United States Army, and great grandson of Colonel Timothy Matlack, whose Quaker ancestry settled in New Jersey in 1677. Colonel Matlack served during the Revolutionary War as Colonel of Militia from 1775 to 1777; Deputy to the State Conference in 1776; Delegate to the Continental Congress in 1780-81; and as Secretary to the Council of State, and Master of the Rolls, in 1781. He died in Philadelphia in 1829.

Mr. Abert was graduated from Princeton College in 1848, and, as a rodman, he commenced his first engineering work upon the extension of the James River and the Kanawha Canal, then terminating at Lynchburg, Virginia. This canal was designed to connect tidewater at Richmond, Virginia, with the Ohio River, by way of the Kanawha, but was never completed beyond Buchanan, Virginia. Between Richmond and Lynchburg it formed the main line of travel and traffic. The only railroad in Virginia at that time connected Richmond with Fredericksburg, with branches to Acquia Creek and Quantico. The route thence to Washington was by steamer on the Potomac. An account—an amusing travesty—of a journey, made in 1842, from Potomac Creek to Fredericksburg may be found in Dickens' "Notes on America."

In 1849 Mr. Abert was called to Washington to make a survey of the Potomac between the aqueduct over the river at Georgetown and the Long Bridge. He prepared a chart of the river, and recommended the removal of parts of the bridge and the substitution of longer spans.

In 1850 he surveyed the canal which enters the Eastern Branch near the Arsenal, and recommended connecting it with the Chesapeake and Ohio Canal, then extending into Washington on the north side of the Smithsonian grounds.

He made a survey of Cape Vincent Harbor, New York, in 1852, and recommended a breakwater. Two years later he surveyed Tar River, North Carolina, and the construction of the lock and dam there was commenced. In 1855 he made a survey of Beaufort Harbor, North Carolina.

* Prepared by the Secretary from notes furnished by Mr. Abert in 1897.

† A memoir of John James Abert, Hon. M. Am. Soc. C. E., is printed in *Proceedings*, Am. Soc. C. E., Vol. XIX, p. 88.

Mr. Abert's interesting report of the survey of New River Inlet, about 40 miles northeast of Wilmington, North Carolina, in 1856, attracted the attention of Professor A. D. Bache, of the United States Coast Survey. The formation at the mouth of New River received careful study. The position of the delta, built within the coast line by storms, is the reverse of the delta of the Mississippi, which, lying without and beyond the coast line, extends its channels to the Gulf of Mexico, like the outstretched fingers of the hand. Formed by silt brought down by the Mississippi, it diverges seaward; the delta of New River, formed by sand brought in by the ocean storms, diverges landward; but, whether extending landward or seaward, each delta exhibits the same anastomising character, in obedience to the dominating force. In New River the storm force dominates the ebb and the fluvial. The hindrance of the ebb was made apparent by conditions observed during the survey. The tide, passing up the channel, and being detained in the bay above, left an unexpended head of water, where the flood again set inward. To improve the channel, a new relation of forces was necessary, in order to increase the volume of outflowing water; and, to attain this, Mr. Abert proposed deepening and widening the channel, following an easy curvature; he also proposed the fixation of the banks by the use of stones and fascines.

The value of the sounds of Carolina as channels for interior navigation has long attracted the attention of engineers. Part of Mr. Abert's report was devoted to the importance of improving these sounds for coastwise trade and for the transportation of heavy guns and material of war. With the exception of a distance of about 244 nautical miles (between Beaufort, North Carolina, and Charleston, South Carolina), interior navigation, without interruption, extends from Norfolk to Fernandina, a distance of about 1 745 nautical miles. A Government torpedo-boat has safely made the passage through inland channels and by way of Romney Marshes, from Charleston to Fernandina, and a comparatively small amount of excavation would make this channel navigable for war vessels of the same size as the *Amphitrite*. Between Appalachicola and Lake Pontchartrain, by connecting the deep sounds along the coast, the route could be continued to New Orleans.

Northward from Beaufort, North Carolina, an uninterrupted channel exists, by way of bays and canals, as far as New York, and thence by way of the Erie Canal to Lake Erie. The Mississippi can then be reached *via* Chicago, by way of the Illinois and Michigan Canal, thus completing the connection between the Sounds of Carolina and the Mississippi River.

Mr. Abert's report was published in *The Wilmington Journal* (Wilmington, North Carolina), on April 23d, 1856. It may be interesting to note that at this period the Southern States conducted pub-

lic improvements within their borders, and many of them appointed a State Engineer to direct all public works.

In 1857 Mr. Abert was employed as Assistant Engineer on the construction of Fort Delaware, on Pea Patch Island, in the Delaware River, about 40 miles below Philadelphia. This was a casemated work, founded on piles and surrounded by a wet-ditch. Its embrasures were provided with wrought-iron shutters, and it was believed to be impregnable to the artillery of that day.

In 1858 Mr. Abert was ordered to the Warrenton Navy Yard, Florida, and placed in charge of the buildings, works, and ground within the Naval Reservation. The works within the reservation—about 7 miles from Pensacola—were varied and interesting. Mr. Abert built a foundry for heavy castings; constructed 200 ft. of sea wall in 30 ft. of water, by using a diving bell; built a machine shop for the repair of ships; submitted plans for a ship house and launching ship; and prepared plans for a ship basin and graving dock, which were approved by a Board of Engineers appointed by the Secretary of the Navy. The foundation of the dock presented especial difficulties. The yard occupies a tract of sandy soil about 3 ft. above the level of the bay. Borings revealed a stratum of clay 40 ft. below the surface, and another stratum was found about 40 ft. lower. It was evident that the dock would have to be built in water. The plan proposed was as follows:

After dredging the entire area, piles were to be driven at not less than 3 ft. from center to center and then sawed off. For the bottom and side walls, concrete was to be deposited from staging—largely floating staging. After closing the outer end of this concrete box temporarily, the bottom and sides were to be finished with heavy granite facing. A wrought-iron floating gate was designed to close the dock when in use. These plans are now in the Bureau of Yards and Docks at Washington.

Mr. Abert was interested in the Bay of Pensacola, and wrote an official letter recommending Pensacola Harbor as the site of a National dockyard and arsenal. A fleet can find anchorage in its waters, and there are 22½ ft. of water on its bar at mean low water. It is connected by rail with Montgomery, Alabama, and the interior of the country, and the Gulf of Mexico does not contain a better harbor.

There was a general suspension of public improvement works at the beginning of the Civil War, and Mr. Abert reported for duty to the Chief Engineer of Bank's Division, at Frederick City, Maryland, in December, 1861. His services in the campaign in the Valley of the Shenandoah are mentioned in the "Personal Recollections of the War," by General David H. Strother (Porte Crayon), published in *Harper's Monthly*, in March, 1867.

Mr. Abert established a flying bridge at Williamsport, Maryland, upon which the retreating army passed over the Potomac. In 1862

he was at Warrenton Junction, Virginia. He was in Nashville when Hood was defeated, and built Fort Garasche, north of the city and overlooking the Cumberland. He served in the campaign before Petersburg, and was with Meade's Army, under orders of Major Michler, of Meade's engineer staff, until the surrender at Appomattox on April 9th, 1865.*

In 1865 and 1866 Mr. Abert was one of a party of engineers called by the United States of Colombia to make surveys of certain localities and to prepare plans of improvement. The party left New York on December 11th, 1865, for Aspinwall, and, after a short visit to Panama, they returned to Aspinwall and embarked in an English steamer for Santa Martha. At this point work began on December 29th.

The surveys and plans of improvement were made for the following localities:

First.—For connecting by rail the Town of Santa Martha with the Town of Cienega, on the delta of the Magdalena.

Second.—For improving the channel through *canos* of the delta, between Cienega and Barranquilla.

Third.—To survey "the Canal de la Pina and *cienigas* (lakes) and *canos* (channels) through which a navigable route can be made from Barranquilla, on the Magdalena, to Sabanilla, the seaport at the mouth." This canal was "to be of such dimensions as to admit at all seasons the passage of the largest steamers navigating the Magdalena."

Fourth.—The next work was at the Island of Margarita, on the Magdalena, about 140 miles above Barranquilla. This island, of great beauty and fertility, is not less than 40 miles in length. The course of the river had been diverted by a freshet from the right side of the island where it flowed past the flourishing city of Monpox—noted for its "dulces," and famous for its ornaments of gold-wire work—to the left side where it passed the site of the insignificant town of Manganguy. Here were held annual fairs, frequented by merchants of Barranquilla, who readily disposed of all their wares to the natives from the surrounding country. Many of these merchants were natives of Bremen and Hamburg. The Monposians asked the engineers to convert the river to its orthodox course. All that was needed for this object was a jetty.

Fifth.—A reconnaissance was made and a map prepared of the Magdalena from Honda (head of navigation) to Barranquilla, a distance of about 525 miles.

The party returned to New York during the latter part of May, 1866. A revolution preceded the arrival of the engineers in Colombia, another followed soon after their return—the chronic condition of this interesting country.

* Mr. Abert's services are mentioned in somewhat more detail in the statement prepared by him for the Society of the Army of the Potomac.

In 1867 Mr. Abert was in charge of repairs at Fort Foote, on the Maryland side of the Potomac, about a mile below Alexandria.

Mr. Abert's next duty (1869) brought up the question of the connection of the Great Lakes with the Mississippi. He was charged with the survey of the Illinois River from La Salle to its mouth at Grafton. The collection of data—of little interest to the general reader—is an essential object in every survey; the following facts are taken from Mr. Abert's report:

The distance from La Salle to Chicago, by way of the river and the Illinois and Michigan Canal, is	99	miles.
From La Salle to Grafton is.....	223	"
From Chicago to Grafton is.....	322	"

The Illinois and Michigan Canal connects Chicago with the Illinois River. The average fall of the river below La Salle is 0.15 ft. per mile, and the entire fall is 29.6 ft.

Mr. Abert submitted an estimate for an improvement by dredging, and also by locks and dams, and pointed out the importance of this route as a navigable connection between the Lakes and the Mississippi. In his report he says:

"Its real importance can be estimated by regarding it as completing a system of water communication between the East and the West, of which the Erie Canal constitutes an important part."

Under the heading "Lake Michigan as a Reservoir," he considers the importance to navigation of the lake as a feeder to the Illinois at low water. The report states:

"The close of the season did not permit a special examination or survey with a view to the complete solution of this question. Facts and theoretical deductions are herein presented, sufficient to indicate the course of examination to be pursued, in order to solve the problem."

Taking the discharge at Hennepin as a basis, and a width of channel of 350 ft., with a velocity of a little more than one mile per hour, a depth of not less than 8 ft. could be given on all bars during the low-water period, which prevails from 60 to 90 days.*

This project was not approved, and in 1868 was declared "impracticable at any reasonable cost."†

The City of Chicago, unaided by Government, has solved the problem of constructing a ship canal. Mr. Abert wrote, in 1897:

"The year 1898 will see the completion of this stupendous work, which will turn the waters of the Great Lakes into the Mississippi."

* Ex. Doc. 16, 40th Cong., 1st Sess., House of Reps. Also Reports of Chief of Engrs., 1868, pp. 445-449.

† Ex. Doc. 116, 40th Cong., 2d Sess., House of Reps.

A writer observes:

"The solution of the problem of disposing of the city sewage has rendered practicable one of the boldest schemes of improvement of internal navigation which has ever been entertained by engineers. When completed, this canal will have a width of 162 ft., a depth of 25 ft., and a length of about 35 miles. Its maximum flow will be about 600 000 cu. yd. per min., and will increase the Illinois eighteen times in the upper part, twelve times at the mouth at low water, and about 25% at St. Louis, as estimated. For details of this remarkable work the reader is referred to the reports of the engineer, in which he will find an account of the machinery used, the channelers, drills, hoisters, cantilever lifts, and dredges, and statements of the value, kind, and quantity of the work done by them. Thirty millions of dollars will be expended before the final completion of the work, if anything can be called final to a people so energetic and liberal as the citizens of Chicago."

In 1869 Mr. Abert was charged with the survey of the Arkansas River, from Fort Gibson, on the Neosho, in Indian Territory, to its mouth, in the Mississippi. The party was recruited in Cincinnati and started in January, 1869. The steam dredge *Octavia* towed the survey boat to Memphis; thence it was towed to Little Rock by a river steamer, and another steamer conveyed it to Fort Gibson, which was reached on February 7th. On the morning after arrival, one of the party, who had been ailing for some days, was pronounced by the surgeon of Fort Gibson to have confluent smallpox. There were no railroads in Arkansas at that time. Without medical aid, and accompanied by threats of the Indians, the survey began. Five sick men, quarantined in camp, were transported from place to place as the survey advanced. One man died, and was buried on the bank of the river.

The following data are gathered from the report: The distance from Fort Gibson to Little Rock is 289½ miles; the fall is about 242½ ft. Discharge measurements, about 30 miles apart, were taken according to the method of Humphreys and Abbot. Careful record was made of the geology and products of the valley. High water prevailing between January and July, no low-water survey of the bars was practicable. For a channel so variable in its course, and so changeable in the depth and position of its bars, any low-water survey would have been of small value until certain important and preliminary work had been completed. Large tracts of river front are washed away during every freshet, and acres of valuable cotton land are annually destroyed by the current. Therefore, no satisfactory estimate for the improvement of the bars can be made until the banks have been fixed. A small amount of work was recommended at but four localities.

The general conclusion stated in the report was:

"That the first object of improvement should be to give permanency to the banks by protecting them from the abrasion of the current."

The regimen of the river would be established by this means, and the alveus of the stream could then be permanently improved.

Maps and diagrams accompany the report, and profiles and cross-sections, of velocities and oscillations, relating to the hydraulics of the river, are fully represented. The survey* was completed in July, 1869.

In 1871 Mr. Abert was engaged on the survey of the Cumberland River, in Kentucky and Tennessee, and the following facts are gleaned from his report:

From the Great Falls, in Pulaski County, Kentucky, to its mouth, the river is 595 miles long. The Great Falls have a vertical descent of 56 ft. The scenery, as far as Point Burnside, is wild and picturesque. At the rapids the rocks rise in vertical escarpments several hundred feet, and the water flows in a thin sheet over the horizontal stratum of limestone, left bare at low water. Here is a geologist's paradise, for myriads of encrinites are entombed in the rock. From Point Burnside to Nashville the distance is 326½ miles, and the descent 232 ft. at low water. From Nashville to the mouth the distance is 92 miles, and the descent 79 ft.—where the river enters the Ohio, about 73 miles above Cairo.

The obstructions to navigation were:

1.—Overhanging trees;
2.—Ledges of rock;
3.—Bars composed of the debris of bluffs;
4.—Bars of gravel and ferruginous sand;
5.—Obstructions in the lower river, such as sunken wrecks—the remains of the war.

Below Point Burnside the method of improvement consisted chiefly in contracting the stream at designated points.

Under the heading, "Resources" the report gives a brief description of the geology and a short history of the coal mines of Pulaski County and of Poplar Mountain. The first mines are above Point Burnside; the Poplar Mountain mine is 58 miles lower down and about 268 miles above Nashville.

The Tennessee Rolling Mills, below Nashville, are at the point where the river passes again into Kentucky. A fine quality of boiler iron is made from the brown hematite found buried on the banks of the river in the form of geodes from 1 to 2 ft. in diameter. These geodes often contain fossil crinoids and crystals of lime. The plates made from this ore are used extensively in the manufacture of the boilers of boats on western waters.

The advantage of a ship canal across the Isthmus connecting Central and South America has long attracted the attention of scientists

* Ex. Doc. 295, 41st Cong., 2d Session.

and engineers. Humboldt devotes several pages to its consideration. Hughes' favorable opinion called public attention to Panama, and Strain's expedition across Darien was led to misfortune by the mythical account of Gisborne. Michler's able survey of Atrato, and Childs' clever report on Nicaragua gave hope of a feasible route; but all these surveys and reports leave the mind in doubt as to which route should be selected for a ship canal. Each possessed advantages and disadvantages. Upon some lines, harbors on the Pacific were separated from harbors on the Gulf by an insurmountable barrier, or one that could only be penetrated by a costly tunnel. On other lines, while the divide opposed no difficult obstruction, harbors are wanting at the termini. To form an intelligent opinion, Mr. Abert attempted to bring together all the information to be found in reports relating to this subject. While in Cincinnati, in 1872, he published a pamphlet having the following title: "Notes, Historical and Statistical, upon the Projected Routes for an Interoceanic Ship Canal between the Atlantic and Pacific Oceans, in which is included a short Account of the Character and Influence of the Canal of Suez, and the Probable Effects upon the Commerce of the World, of the Two Canals, Regarded either as Rivals, or as Parts of one System of Interoceanic Travel."

This pamphlet* was given a wide publication. It was printed by Murat Halsted in a broadside of *The Cincinnati Commercial.* It was favorably commented on by R. J. Walker, ex-Secretary of the Treasury, by W. H. Seward, Secretary of State; by Nathan Appleton; by the editor of the *Journal* of the Franklin Institute; and by *The Nation,* of New York. Though valuable at the time of publication, its information has been superseded by later surveys, and by the work done on the Nicaragua and Panama Canals; but a navigable way across the Isthmus is still an unsolved problem.

In 1873 Mr. Abert was called to important duty upon the Atlantic seaboard. By order of the Secretary of War, he was placed in charge of a geographical division beginning at Washington, D. C., and terminating at Wilmington, North Carolina. His annual reports relate to the surveys and improvements of rivers and harbors in Maryland, Virginia, and North Carolina. Among the more important are those relating to Norfolk Harbor, Elizabeth, York, Rappahannock, and Roanoke Rivers, the reclamation of the flats at Washington, and the survey of an inland line of navigation between Norfolk and Wilmington.

The plan for the reclamation of the Potomac flats was submitted to a Board of Engineers, appointed by General A. A. Humphreys. The problem was complicated with the sanitary conditions, caused by a large flat extending in front of the city. Beginning with a width of ½ mile at Georgetown, the river widens to 1 mile at the Long Bridge,

* Published by R. W. Carroll and Company, Cincinnati, 1872.

about 3 miles lower down, and the flats were traversed by two channels (in 1790 by three channels). It was proposed to reclaim this area, near the Washington side, by a deposit raised above the level of the highest water, and conforming in outline to the hydrographic curves. The area covered by the reclamation was about 700 acres—an addition to the city largely exceeding in value the money to be expended upon it.

The canal to connect the waters of Norfolk Harbor with the Cape Fear River at Wilmington is so important that it deserves some notice. It may be described briefly under three heads:

1.—An inland navigation, near the coast, and chiefly by way of the sounds;

2.—Physical features of the coast;

3.—Historical notes and old maps.

In relation to the canal, estimates are submitted, but Mr. Abert recommends that nothing be done until further examinations have been made. Other routes are mentioned, and an examination of each is regarded as necessary before the problem of location can be solved. Description is given of the Kearney route, and the report of Colonel Kearney is printed in the appendix. Under the headings, "Physical Description" and "Coast Line," quotations are made from the following maps: Hariot's, 1585; Lauson, 1708; Wimble, 1738; Mouzin, 1775; Atlantic Neptune, 1780; Lewis, 1795; United States Coast Survey, 1875. Copies of these maps accompany the report. A study of them exhibits interesting changes in the coast line. Attention is called to the progressive closing of the inlets, and to the southward and southwestward movement of the sand drives.

Under the heading "Changes of the Inlets," comparison is made of the condition at the time of survey and the condition represented on the map of Hariot (1584). Comparison is also made with the statement of Colonel William Byrd, Commissioner on the part of Virginia and North Carolina. Colonel Byrd's observations, made in 1713, are contained in the famous Westover manuscript. The first accurate mapping of the coast line will be found in the charts of the Coast Survey. With this aid we can trace the rate of "Hatteras' advancing foot," and measure the retreat of the coast line between New River Inlet and Masonborough, an inlet near Wilmington.

Five expeditions were sent out by Sir Walter Raleigh, between 1584 and 1590, to the coast of Virginia—now North Carolina. Extracts are given from voyages and travels, published by De Bry Brothers, in Frankfort in 1590, and from Hakluyt's Collection "reprinted in London in 1600." These extracts are accompanied by comments in which Mr. Abert endeavors to follow the steps of the exploring party after landing at Roanoke Island. No permanent settlement

was made by the five expeditions sent by Sir Walter to the coast of Virginia, but the writers mentioned supply valuable matter to one who wishes to study the changes in the coast.

Included in the appendix is an interesting letter from Colonel Marshall Parks, President of the Albemarle and Chesapeake Canal, also one from Mr. McAlpin C. Engs. Tables of statistics of trade are added. If not the most interesting, this report includes much valuable matter. Other reports by Mr. Abert, on the rivers and harbors of Virginia, Maryland, and North Carolina, will be found in the Reports of the Chief of Engineers between the years 1873 and 1890.

Mr. Abert was elected a Member of the American Society of Civil Engineers on September 21st, 1870.

LOUIS FREDERIC GUSTAVE BOUSCAREN, M. Am. Soc. C. E.*

DIED NOVEMBER 6TH, 1904.

Louis Frederic Gustave Bouscaren was born on the Island of Guadeloupe, on August 26th, 1840. Both his parents were of old West Indian families of French descent, his great-grandfather having been awarded a large part of the Island of Guadeloupe, with the title of Marquis, by the French Government for distinguished services rendered by him as a member of the French Military Engineer Corps.

In 1850 the parents of Mr. Bouscaren, who were quite wealthy, came to the United States, settling on a large tract of land which they had purchased in Grant County, Kentucky, a part of which, with the old homestead, is still retained by the family.

Mr. Bouscaren, who was the oldest son of eight children, received his earlier education at home, but at the age of twelve he was sent to St. Xavier's College at Cincinnati, Ohio. Two years later he was sent to France, where he entered the Lycée St. Louis, one of the great Government schools in Paris, remaining there until he was twenty, after which he entered L'Ecole Centrale des Arts et Manufactures, from which he was graduated with high honors, in 1863, as "Ingénieur des Arts et Manufactures."

His first employment, after his return, was as Draftsman in the office of S. Hannaford and Sons, leading architects in Cincinnati, and, later, while awaiting an opportunity to become connected with outside engineering work, with the firm of Lane and Bodley, manufacturers of mill machinery and engines.

In 1865 Mr. Bouscaren was appointed Assistant Engineer of Maintenance-of-Way on the Ohio and Mississippi Railroad, under the late Thomas D. Lovett, M. Am. Soc. C. E., Chief Engineer, and later un-

* Memoir prepared by G. H. Benzenberg, President, Am. Soc. C. E.

der the late E. C. Rice, M. Am. Soc. C. E., who succeeded Mr. Lovett. He served under these two engineers in various positions for the next 11 or 12 years In 1868-69, as Assistant to Mr. Rice, he made the preliminary and location surveys, and later was in charge of construction of the St. Louis, Vandalia and Terre Haute Railroad. From 1869 to 1872 he served as Principal Assistant to Mr. Rice on the St. Louis and South Eastern Railroad, at the same time acting as Chief Engineer of the O'Fallon and Belleville Railroad. In 1872-73 he was Principal Assistant on the Cairo and Vincennes Railroad. In these several positions Mr. Bouscaren showed a marked faculty for details, which, together with his close application and skill, led to his being entrusted with greater responsibilities.

In 1873, Mr. Lovett, then Principal Engineer of the Cincinnati Southern Railway, engaged him to prepare the specifications for, and to take charge of the construction of, the great railway bridge for this road over the Ohio River at Cincinnati. Immediately following this he was appointed First Assistant Engineer, Department of Construction, of the Cincinnati Southern Railway, which position he held until late in 1876, when, upon the resignation of Mr. Lovett, he succeeded him as Consulting and Principal Engineer, and completed the construction of the road.

In the preparation of the plans and specifications for this bridge, which was to embody, at that time, the longest truss span in the world, Mr. Bouscaren entered upon a comprehensive series of tension and compression tests of full-sized bridge members and worked out new formulas based upon the results of these tests. He also introduced in his specifications new forms for considering concentrated loads, and in many ways advanced the requirements for bridge construction, especially in the matter of details, so that his specifications for the many bridges which he, as Principal Assistant and later as Chief Engineer, built for the Cincinnati Southern, were accepted as models by many engineers.

Among many bridges, the noted Kentucky River Bridge may be mentioned as the first great cantilever bridge in this country. This bridge was built by the late C. Shaler Smith, M. Am. Soc. C. E., and was first designed to be a continuous bridge, but Mr. Bouscaren changed this design, fixing the points of contraflexure by cutting the lower chords, enclosing the ends in loose sleeves.

The line of the Cincinnati Southern Railway runs through very hilly and mountainous country, and the many difficulties natural to such a location were successfully overcome by Mr. Bouscaren's engineering skill. The construction included some twenty-seven tunnels, the most important of which was the King's Mountain Tunnel, more than 4 000 ft. long.

In 1881, when the Cincinnati Southern Railway was leased by the

Erlanger Syndicate, Mr. Bouscaren was made Consulting and Chief Engineer of the entire railroad system controlled and operated by this Syndicate. In this capacity he constructed the New Orleans and North Eastern Railroad, and completed the construction of the Vicksburg, Shreveport and Pacific Railroad. He also did a large amount of reconstruction work on the Alabama Great Southern and on the Vicksburg and Meridian Railroad. In connection with the New Orleans and North Eastern Railroad, he constructed a pile trestle, 21 miles in length, where the railroad crosses the Lake Pontchartrain marshes. All the timber used in this trestle was creosoted, for which purpose he designed and had built the most extensive creosoting plant in the country at that time.

In 1886 Mr. Bouscaren resigned his position as Chief Engineer, and opened an office in Cincinnati as Consulting Engineer. The reputation which he had established as a careful, capable and conscientious engineer secured for him a considerable amount and variety of work. He was engaged in the construction of a number of bridges across the Ohio River, among them the Central Bridge between Cincinnati and Newport, which he designed, and the Chesapeake and Ohio Railroad Bridge. He also had charge of the strengthening of the cables of the suspension bridge between Cincinnati and Covington, and designed and constructed the Fourth Street Bridge over the Licking River in Covington, Ky. He was a member of the Commission appointed by President Cleveland to examine into and report upon the best plan to bridge the North River.

From 1887 to 1891 Mr. Bouscaren was Chief Engineer for, and built, the Covington, Ky., Water-works; he also built the Norwood Water-works. In July, 1896, the Board of Trustees, "Commissioners of Water-works," appointed him Chief Engineer of the new works which were to be constructed for the City of Cincinnati, in which work, Charles Hermany, Past-President, Am. Soc. C. E., and the writer were associated with him as Consulting Engineers. To this work he devoted his entire time and his best skill and energy up to the day of his death, and so far as the same was planned by him, it will stand as a lasting monument of his ability and eminence as an engineer.

Into all of his work Mr. Bouscaren introduced an individuality based upon his independence of research and conclusion, which very often led him in advance of contemporaneous practice. He was a close student and a constant reader and had acquired a very large library of scientific and professional works. His plans and specifications were always clear, comprehensive and explicit, and he would never allow a contractor to swerve or deviate in the least from a full compliance with every obligation of the contract and specifications. He was firm, strict and insistent, yet at no time unjust and unfair.

Honesty of purpose and integrity were leading characteristics in all his business transactions.

Socially Mr. Bouscaren was of a delightful and generous disposition, always unselfish and unassuming, and ever courteous in his demeanor toward his assistants and co-laborers. Being a devout member of his Church, he was also liberal in aiding her charities.

On April 18th, 1876, Mr. Bouscaren married Miss Helen Seymor Lincoln, daughter of Timothy D. Lincoln, a distinguished lawyer of Cincinnati. Twenty-five years of happy home life followed this union, which grew to a family circle of three sons and two daughters. Mrs. Bouscaren's death, in July, 1901, was a severe blow from which he never fully recovered, especially as his children shortly after left their home to attend school, the oldest son being at the Massachusetts Institute of Technology, the second son studying law at Yale, while the daughters attended school in the Convent at Washington, D. C.

Shortly after attending the Annual Meeting of the American Society of Civil Engineers, in January, 1903, Mr. Bouscaren was attacked with severe pains and internal hemorrhages which compelled him to avoid much walking or exercise, and which necessitated his remaining much of the time either at his home or at the hospital, where he underwent two painful operations—which gave him little relief—followed by long periods of suffering, during which he displayed wonderful patience and fortitude, regretting only that he could not oversee and finish the work he had undertaken. Despite all the efforts of eminent surgeons and physicians, he became so weak that on November 6th, 1904, surrounded by his children, his brother and sisters, he quietly passed away.

Thus ended an active, sincere and useful life, full of good deeds and creditable work, whose record is that of an honest, upright, capable and eminent engineer.

On April 7th, 1875, Mr. Bouscaren was elected a Member of the American Society of Civil Engineers. He served as a Member of the Board of Direction in 1881; and held the office of Vice-President at the time of his death. He also served on a number of special and other committees, and was a frequent contributor to the professional papers and discussions.

In June, 1880, he was elected a Member of the Société des Ingénieurs Civils de France, and, on December 7th, a Member of the Institution of Civil Engineers of Great Britain.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

(INSTITUTED 1852.)

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OCTOBER, 1907.

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The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER.....5913 Columbus.
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PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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MINUTES OF MEETINGS.

OF THE SOCIETY.

September 18th, 1907.—The meeting was called to order at 8.30 P. M.; Director A. L. Bowman in the chair; Chas. Warren Hunt, Secretary; and present, also, 95 members and 21 guests.

A paper by G. L. Robinson, Assoc. M. Am. Soc. C. E., entitled "A Description of the Recently Installed Sewage Disposal Works for the Village of Ballston Spa, New York," was presented by the author, and discussed by G. S. Webster, M. Am. Soc. C. E.

The Secretary announced the following deaths:

ARTHUR HENRY BIRKS, elected Junior, April 5th, 1904; Associate Member, November 7th, 1906; died August 29th, 1907.

GEORGE WASHINGTON PLYMPTON, elected Member, January 29th, 1868; died September 11th, 1907.

Adjourned.

October 2d, 1907.—The meeting was called to order at 8.30 P. M.; Director Allen Hazen in the chair; Chas. Warren Hunt, Secretary; and present, also, 190 members and 30 guests.

The minutes of the meeting of September 4th, 1907, were adopted as printed in *Proceedings* for September, 1907.

A paper by D. W. Krellwitz, Jun. Am. Soc. C. E., entitled "Reinforced Concrete Towers," was presented by the Secretary.

A paper by Chester Wason Smith, Assoc. M. Am. Soc. C. E., entitled "Reinforced Concrete Pipe for Carrying Water Under Pressure," was presented by the Secretary, who also read communications on the subject by Messrs. F. Teichman and J. R. Worcester. The paper was discussed by Messrs. R. W. Lesley and Thomas H. Wiggin.

Ballots for membership were canvassed, and the following candidates elected:

As Members.

Charles Chapman Anthony, Philadelphia, Pa.
Reuben Edwin Bakenhus, Newport, R. I.
B J Dalton, Lawrence, Kans.
William Thomas Dougan, New York City.
Homer Johnston Gault, Selden Station, N. Mex.
George Higgins, Melbourne, Victoria, Australia.
Henry F Jonas, Houston, Tex.
Willard Kent, Narragansett Pier, R. I.
Walstan Emile Knobloch, New Orleans, La.
Adolph Thomas Kroeber, New York City.
Stephen Arnold Mitchell, Kansas City, Mo.
Eugene Mowlds, Edge Moor, Del.
Joseph Pettus Newell, Portland, Ore.
William Collins Phelps, New York City.
Herbert Leroy Potter, Brooklyn, N. Y.
Henry Atherton Schulze, San Francisco, Cal.
James Shand, Salina Cruz, Oaxaca, Mexico.
Edward Peter Shuman, Vigan, Philippine Islands.
Jesse Baker Snow, New York City.
Edwin Brinton Temple, Philadelphia, Pa.
John Hermon Terry, Philadelphia, Pa.
William Charles Weeks, Spokane, Wash.
Benjamin Emanuel Winslow, San Francisco, Cal.

As Associate Members.

Algernon Brown Alderson, West Hartford, Conn.
Kay Alexander, St. Regis, Mont.
Percival Stevens Baker, Philadelphia, Pa.

John Berger, New York City.
Charles Ernest Beugler, Oakland, Cal.
Edward Elisha Bratton, Philadelphia, Pa.
Harry Frank Cameron, Cebu, Philippine Islands.
George Payson Carver, Beverly, Mass.
Ira Mason Chace, Jr., Tucson, Ariz.
Edward Merriam Chadbourne, San Francisco, Cal.
Robert Lloyd Chamberlaine, Baltimore, Md.
Paul Chipman, Montreal, Que., Canada.
Edward Walter Cunningham, Cleveland, Ohio.
George Jacob Davis, Jr., Madison, Wis.
Harry Whiting Dennis, Niagara Falls, N. Y.
Gotthard Vincent Dieden, Leesville, Va.
Thomas Benson Downer, Mojave, Cal.
Chester Centennial Fisher, Meridian, Idaho.
George Munro Forrest, New York City.
Edward James Fucik, Chicago, Ill.
Joseph Harrington Gandolfo, New York City.
Leon Lincoln Gay, Boise, Idaho.
August Gundersen, Detroit, Mich.
Harry Macy Harps, New York City.
Allan Collins Harrington, Albion, N. Y.
Jay Butler Harris, Los Angeles, Cal.
Newton Fisher Hopkins, Pittsburg, Pa.
Harold Wellington Horne, New York City.
Herbert Frank Howe, Cebu, Philippine Islands.
Hyotaro Inagaki, Taipeh, Formosa, Japan.
Willard Edward Ingram, Chicago, Ill.
Edwin Samuel Johnson, Miami, Fla.
Lorin Acil Keith, Mansfield, Ohio.
Jay Cowden Lathrop, San Francisco, Cal.
Clifford Milton Leonard, Chicago, Ill.
Javier Diaz Lombardo, Necaxa, Puebla, Mexico.
Clarence William Meyers, New York City.
Howard Scott Morse, Glendive, Mont.
Charles Andrew Pohl, Lyons, N. Y.
Sam Graham Porter, Holly, Colo.
Charles Henry Preston, Jr., Waterbury, Conn.
Clinton Leroy Richardson, Atlanta, Ga.
Shigeki Sekiba, Beaver Falls, Pa.
Julian Chatard Smith, Philadelphia, Pa.
Gabriel Roberts Solomon, Atlanta, Ga.
Herbert Harris Starr, New Haven, Conn.
William Lawrie Stevenson, Philadelphia, Pa.
James Wolfe Sussex, Wenatchee, Wash.
Eugene Adams Yates, New York City.

As Associate.

George Nathan Cole, New York City.

The Secretary announced:

The transfer of the following candidates by the Board of Direction on October 1st, 1907:

From Associate Member to Member.

William Lowe Brown, New York City.
Bertram Henry Majendie Hewett, New York City.
William Mayo Venable, Miami, Fla.

The election of the following candidates by the Board of Direction:

As Juniors.

On April 2d, 1907:

Norris Raymond Macklem, Jackson, Mich.

On September 3d, 1907:

William George Broadhurst, New York City.
Matthew DeTobin Kelley, San Juan, Porto Rico.

On October 1st, 1907:

James Madison Barker, Boston, Mass.
Sidney Raymond Bellows, Conimicut, R. I.
Hiram Nelson Bishop, Berkeley, Cal.
George Earle Burnham, Manila, Philippine Islands.
Arthur William Bushell, Manila, Philippine Islands.
Henry William Corp, Providence, R. I.
Clinton Alonzo Curtis, Ft. Edward, N. Y.
Charles Louis Dimmler, Berkeley, Cal.
Robert Leslie Holmes, Boyce, La.
Harold Edmund Miller, Providence, R. I.
Julio Daniel Montero, Güines, Cuba.
Jabez Curry Nelson, Birmingham, Ala.
Stephen Henley Noyes, Long Island City, N. Y.
Edwin James Potter, Bridgeton, R. I.
John Kuhn Scott, Pittsburg, Pa.
Everett Harold Swett, Providence, R. I.
William Albert Yeo, New York City.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

October 1st, 1907.—Past-President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bowman, Christie, Gibbs, Hazen, Hodgdon, Knap, Schneider, Smith, Stearns, and Swensson.

A modification of the form of Ballot List, and a circular to be issued to the Corporate Members with the next list, were adopted.

A resolution of thanks for the hospitality received by the Society in Mexico was adopted and ordered to be suitably engrossed and forwarded to the proper parties.

Applications were considered and other routine business transacted.

Three Associate Members were transferred to the grade of Member, and seventeen candidates for Junior were elected.*

Adjourned.

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* See page 426.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, November 6th, 1907.—8.30 P.M.—Ballots for membership will be canvassed, and a paper entitled "Water Purification at St. Louis, Mo.," by Edward E. Wall, M. Am. Soc. C. E., will be presented for discussion.

This paper was printed in *Proceedings* for September, 1907.

Wednesday, November 20th, 1907.—8.30 P. M.—A paper entitled "The Reinforced Concrete Work of the McGraw Building," by William H. Burr, M. Am. Soc. C. E., will be presented for discussion at this meeting.

This paper is printed in this number of *Proceedings*.

Wednesday, December 4th, 1907.—8.30 P. M.—Ballots for membership will be canvassed, and a paper entitled "Invar (Nickel-Steel) Tapes on the Measurement of Six Primary Base Lines," by Owen B. French, M. Am. Soc. C. E., will be presented for discussion.

This paper is printed in this number of *Proceedings*.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all meetings:

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Society of Engineers, 17 Victoria Street, Westminster, S. W., England.

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Civil Engineers' Club of Cleveland, 718 Caxton Building, Cleveland, Ohio.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa.

Engineers' Society of Western Pennsylvania, 803 Fulton Building, Pittsburg, Pa.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

Louisiana Engineering Society, 604 Tulane-Newcomb Building, New Orleans, La.

Engineers' Club of Central Pennsylvania, Corner Second and Walnut Streets, Harrisburg, Pa.

Engineers' and Architects' Club of Louisville, Ky., 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

Teknisk Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Société des Ingénieurs Civils de France, 19 Rue Blanche, Paris, France.

Svenska Teknologförenigen, Brunkebergstorg 18, Stockholm, Sweden.

Institute of Marine Engineers, 58 Romford Road, Stratford, London, E., England.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Pacific Northwest Society of Engineers, 617–618 Pioneer Building, Seattle, Wash.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Memphis Engineering Society, Memphis, Tenn.

Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

The Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Institution of Engineers of the River Plate, Buenos Aires, Argentine Republic.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Cleveland Institute of Engineers, Middlesbrough, England.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Rochester Engineering Society, Rochester, N. Y.

Brooklyn Engineers' Club, 197 Montague Street, Brooklyn, N. Y.

Montana Society of Engineers, Butte, Montana.

LIST OF NOMINEES FOR THE OFFICES TO BE FILLED AT THE ANNUAL ELECTION, JANUARY 15, 1908.

The following list of nominees for the offices to be filled at the Annual Meeting, January 15th, 1908, received from the Nominating Committee, was presented to the Board of Direction at its meeting on October 1st, 1907. The list has already been mailed to all Corporate Members.

For President, to serve one year:

CHARLES MACDONALD, New York City.

For Vice-Presidents, to serve two years:

GEORGE F. SWAIN, Boston, Mass.
MORDECAI T. ENDICOTT, Washington, D. C.

For Treasurer, to serve one year:

JOSEPH M. KNAP, New York City.

For Directors, to serve three years:

CHARLES L. HARRISON, New York City, representing District No. 1.
GEORGE W. KITTREDGE, New York City, representing District No. 1.
DEXTER BRACKETT, Boston, Mass., representing District No. 2.
GARDNER S. WILLIAMS, Ann Arbor, Mich., representing District No. 3.
HORACE ANDREWS, Albany, N. Y., representing District No. 3.
CHARLES S. CHURCHILL, Roanoke, Va., representing District No. 6.

SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

In reference to this work, the Appendix* to the Annual Report of the Board of Direction for the year ending December 31st, 1906, contains a summary of all searches made to that date.

* *Proceedings*, Vol. XXXIII, p. 20 (January, 1907).

ACCESSIONS TO THE LIBRARY.

(From September 11th to October 7th, 1907.)

DONATIONS.*

RIVER DISCHARGE.

Prepared for the Use of Engineers and Students. By John Clayton Hoyt and Nathan Clifford Grover, Assoc. Members, Am. Soc. C. E. Cloth, 9 x 6 in., illus., 8 + 137 pp. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1907. $2.00.

The increase in the development of the water resources of the United States has created a demand for information relative to the flow of streams. Much has been written on the methods of measuring stream flow, but such information is scattered through periodicals and Government reports and is not readily accessible to engineers and students. Text-books also are indefinite in their descriptions, usually stating only general methods. The authors state that, in this book, they have brought together all available information in regard to the best practice in this work. They have added much that is new, such as descriptions of conditions necessary for good gauging stations at which measurements of discharge may be made, either by weir, current meters, floats, or slope; the selection, establishment and maintenance of gauging stations; the details of field work of discharge measurements, and office methods for computing the regimen of flow. It is also stated that the scope of this discussion of surface flow includes methods of measuring and computing stream flow; laws which govern such measurement and the degree of accuracy obtainable; the phenomena which affect the flow of streams; and the uses to which the data are applicable. The Contents are: Introduction; Conditions Affecting Stream Flow; Instruments and Equipment; Velocity-Area Stations; Weir Stations; Discussion and Use of Data; Hydraulic Tables. There is an index of five pages.

THE COPPER MINES OF THE WORLD.

By Walter Harvey Weed. Cloth, 9 x 6 in., illus., 14 + 375 pp. New York and London, Hill Publishing Company, 1907. $4.00.

This book is divided into two parts. In the first part the author gives a general account of copper deposits, their distribution, geologic occurrence, their structural, mineralogical and chemical relations, etc. The second part is a purely descriptive account of the world's most important copper mines, no attempt being made to present the facts concerning the financial aspect of such properties. The Chapter headings are: Distribution of Copper Deposits; Production of Copper; Mineralogy of Copper; Geologic Distribution and Occurrence; Outcrops and Gossan Formation; Genesis of Copper Deposits; Classification of Copper Deposits; Copper Mines of Europe; Copper Deposits of Africa; Copper Deposits of Asia; Copper Mines of Japan; Copper Deposits of Australasia; Copper Mines of South America; Copper Deposits of the West Indies and Central America; Copper Deposits of Canada and New Brunswick; Copper Deposits of Mexico; Copper Deposits of the United States. There is an index of nine pages.

JAHRBUCH FÜR DAS EISENHÜTTENWESEN.

(Ergänzung zu *Stahl und Eisen.*) Ein Bericht über die Fortschritte auf allen Gebieten des Eisenhüttenwesens im Jahre 1904. Im Auftrage des Vereins deutscher Eisenhüttenleute bearbeitet von Otto Vogel. V. Jahrgang. Cloth, 10 x 7 in., illus., 16 + 448 pp. Düsseldorf, A. Bagel, 1907. $2.50.

Like former numbers, this Annual is issued as a supplement to *Stahl und Eisen.* It contains a general review of periodical literature of the metallurgy of iron for 1904, the authorities quoted numbering more than 3 000 as against 2 600 for 1903. Besides the bibliographies, statistics of the iron industry and a review of patent literature are given. The following subjects are indexed: fuels and firing; slags, ores and the various kinds of iron; the working of iron, and its

* Unless otherwise specified, books in this list have been donated by the publisher.

properties; alloys; and testing the material. Abstracts of important articles are given in addition to their sources. The bibliographies are arranged by subject, and the index is divided by subject and author. It is stated by the editor that after this number, the publication of *Jahrbuch für Eisenhüttenwesen* will be discontinued, owing to the fact that a quarterly, *Zeitschriftenschau*, which covers the same ground, has been combined with *Stahl und Eisen*, and issued as a weekly, thereby keeping the subject-matter up to date in a manner not possible in a yearly issue. The Chapter headings are: Allgemeiner Teil; Brennstoffe; Feuerungen; Feuerfestes Material; Schlacken; Erze; Werksanlagen; Roheisenerzeugung; Giessereiwesen; Erzeugung des Schmiedbaren Eisens; Verarbeitung des Schmiedbaren Eisens; Weiterverarbeitung des Eisens; Eigenschaften des Eisens; Legierungen und Verbindungen des Eisens; Materialprüfung.

RECOLLECTIONS OF AN ILL-FATED EXPEDITION

To the Headwaters of the Madeira River in Brazil. By Neville B. Craig. In Coöperation with Members of the Madeira and Mamoré Association of Philadelphia. Cloth, 9 x 6 in., illus., 479 pp. Philadelphia and London, J. B. Lippincott Company, 1907. $4.00 net.

The Madeira and Mamoré Association is composed of men who, in 1878, were sent out to Brazil by the American contractors—P. & T. Collins and Mackie, Scott & Co.—to survey and construct the Madeira and Mamoré Railway around the falls and rapids of the Upper Madeira River. This railway, with the proposed steamship lines, was to form a system of international transportation between the United States and the interior of Bolivia and to open the South American continent to the markets of the world. The enterprise failed by reason of litigation which ruined the contracting firms. At a reunion of the Association in 1903, it was determined to have a history of the enterprise written by a member of the expedition. An instalment of the proposed history was issued in pamphlet form at each subsequent reunion of the Association. This method of presentation being found to be impracticable by reason of the constant necessary amplification and correction of the printed parts, the present publication in book form was determined upon, and this the author presents as "a true history of one of the most remarkable enterprises ever undertaken by Americans on foreign soil."

SPIRALS FOR STREET RAILWAY CURVES

And Easement Curves for Street Railway Branch-Offs: Complete Formulas and Tables. Leather, 7 x 4 in., illus., 96 pp. Steelton, Pa., The Pennsylvania Steel Company, Frog and Switch Department, copyright 1906.

The spiral system, as presented in this book, is that used by the Pennsylvania Steel Company. It consists of a transition formed of arcs of diminishing radii and is calculated upon the center line of track. The first seven pages of the book are devoted to various problems, the solution of which, as stated in the preface, presents sufficient information to enable any data required for the laying out or construction of track to be readily secured. The remainder of the book relates to: Standard Spirals, The Pennsylvania Steel Co.; Center Line Data; Tables Giving Elements of Spirals for Inner Gage Line Lengths of Rails and Tie Rod Spacing for Various Gages; Middle Ordinates for 10-Foot Chords; Wheel Contours. At the end of the book are illustrations of specialties in frogs, switches and switchstands.

Gifts have also been received from the following:

Am. Ry. Master Mechanics' Assoc. 1 bound vol.
Am. Steel & Wire Co. 1 bound vol.
Boston & Maine R. R. Co. 1 pam.
Brown, C. C. 1 pam.
Canada-Dept. of Marine and Fisheries. 4 vol.
Chicago, Ill.-City Statistician. 4 pam.
Chicago & Northwestern Ry. Co. 1 pam.
Clarke, D. D. 1 bound vol.
Cleveland, Ohio-Water-Works Div., Board of Public Service. 1 vol.
Denver & Rio Grande R. R. Co. 1 pam.
Engineering Record. 2 bound vol.
Eng. Standards Comm. 3 pam.
Engrs.' Soc. of Western Pennsylvania. 1 pam.
Exploration Co., Limited. 1 pam.
Fisk & Robinson. 1 pam.
Glasgow & South-Western Ry. Co. 1 pam.
Gurley, W. & L. E. 1 bound vol.
Hocking Valley Ry. Co. 1 pam.
Ill.-State Geol. Survey. 1 bound vol.
Indiana-Dept. of Geology and Natural Resources. 1 bound vol.
Indiana Eng. Soc. 1 pam.
Inst. of Marine Engrs. 1 bound vol.
Institution of Civ. Engrs. of Ireland. 1 vol.
Iron and Steel Inst. 1 bound vol.
Italy-Royal Minister of Foreign Affairs. 1 pam.
Ives, H. C. 1 pam.

Jacksonville, Fla.-Trustees for the Waterworks and Impvt. Bonds. 1 pam.
Japan-Imperial Earthquake Investigation Comm. 2 vol.
Kanawha & Mich. Ry. Co. 1 pam.
Liverpool Eng. Soc. 1 pam.
Madras, India-Public Works Dept. 1 pam.
Maine Central R. R. Co. 1 pam.
Mexico-Direccion Gen. de Obras Publicas. 1 vol.
Mich. Coll. of Mines. 1 vol.
Middletown, Conn.-Board of Water Commrs. 1 pam.
Minneapolis, St. Paul & Sault Ste. Marie Ry. Co. 1 pam.
Nashville, Chattanooga & St. Louis Ry. Co. 1 pam.
National Assoc. of Cotton Mfrs. 1 bound vol.
National Fire Protection Assoc. 1 pam.
New South Wales-Chf. Commr. of Govt. Railways. 1 pam.
New York City-Board of Water Supply. 4 pam.
New York City-Dept. of Docks and Ferries. 3 bound vol.
New York City Record. 1 bound vol.
New York, Ontario & Western Ry. Co. 1 pam.
North, E. P. 1 pam.
Ohio-Bureau of Inspection and Supervision of Public Offices. 2 pam.
Ontario, Canada-Bureau of Mines. 2 bound vol.
Osborn, E. E. 1 pam.
Poor's R. R. Manual Co. 1 bound vol.
Rust, C. H. 1 pam.
St. Petersburg Soc. of Civ. Engrs. 4 pam.
Smithsonian Institution. 1 vol.
Somerville, Mass.-City Clerk. 1 bound vol.
Stone & Webster. 1 pam.
Switzerland-Eidgen. Hydrometrische Bureau. 1 pam.
Toledo & Ohio Central Ry. Co. 1 pam.
Toledo, Peoria & Western Ry. Co. 1 pam.
Transvaal-Chf. Engr. of the Rand Water Board. 1 pam.
U. S. Chf. of Div. of Publications, Dept. of Agri. 1 pam.
U. S. Engr. School. 1 pam.
U. S. Forest Service. 2 pam.
U. S. Geol. Survey. 2 pam.
U. S. Interstate Commerce Comm. 13 pam.
U. S. Lake Survey Office. 1 pam.
U. S. Naval War Records Office and Library. 1 pam.
U. S. Office of Public Roads. 2 pam.
Walker, J. W. G. 1 bound vol.
Western Australia-Acting Comm. of Railways. 1 bound vol.
Whitford, N. E. 3 bound vol.
Wilmington, Del.-Water Dept. 1 pam.

BY PURCHASE.

Handbook of the Trees of the Northern States and Canada, East of the Rocky Mountains. Photo-descriptive. By Romeyn Beck Hough. Lowville, N. Y., Published by the Author, 1907.

Irrigation: Its Principles and Practice as a Branch of Engineering. By *Sir* Hanbury Brown. New York, D. Van Nostrand Company, 1907.

Public Health, Volume XXXII, Pts. 1 and 2. Papers and Reports Presented at the Thirty-fourth Annual Meeting of the American Public Health Association, Mexico City, Mexico, December 3, 4, 5, 6, 7, 1906. Columbus, Ohio, Fred. J. Heer, 1907.

SUMMARY OF ACCESSIONS.

From September 11th to October 7th, 1907.

Donations (including 7 duplicates)	101
By purchase	4
Total	105

MEMBERSHIP.

ADDITIONS.

(September 10th to October 8th, 1907.)

MEMBERS.		Date of Membership.
BAKENHUS, REUBEN EDWIN. Naval Training Station, Newport, R. I.		Oct. 2, 1907
BROWN, WILLIAM LOWE. Res. Engr., Penn., N. Y. & L. I. R. R., 564 West 33d St., New York City.	Assoc. M. M.	Sept. 6, 1905 Oct. 1, 1907
CARMALT, LAURANCE JOHNSON. Prin. Asst. Engr., Atlantic Ave. Impvt., Long Island R. R., Flatbush Ave. Terminal, Brooklyn, N. Y.		May 1, 1907
DOUGLAS, WALTER JULES. District Bldg., Washington, D. C.		April 3, 1907
HEWETT, BERTRAM HENRY MAJENDIE. Gen. Res. Engr., River Tunnels Section, North River Div., P. R. R. Tunnels, 564 West 33d St., New York City.	Assoc. M. M.	April 5, 1905 Oct. 1, 1907
KENT, WILLARD. Narragansett Pier, R. I.		Oct. 2, 1907
MCCULLOCH, ROBERT AUSTEN. Chf. Engr. with R. F. Almirall, 51 Chambers St., New York City.	Jun. Assoc. M. M.	Sept. 2, 1902 Sept. 7, 1904 Sept. 3, 1907
MOWLDS, EUGENE. Care, Am. Bridge Co., Edge Moor, Del.		Oct. 2, 1907
POTTER, HERBERT LEROY. 511 Eighth St., Brooklyn, N. Y.		Oct. 2, 1907
ROBERTS, WILLIAM JACKSON. Assoc. Prof., Math. and Civ. Eng., State Coll. of Washington, Pullman, Wash.	Assoc. M. M.	June 6, 1900 Sept. 3, 1907
TEMPLE, EDWARD BRINTON. Asst. Chf. Engr., P. R. R. Co., Broad St. Station, Philadelphia, Pa.		Oct. 2, 1907
ASSOCIATE MEMBERS.		
ADDISON, CHARLES LAMBERT. Asst. to Pres., Long Island R. R. Co., Long Island City, N. Y.		May 1, 1907
ALDERSON, ALGERNON BROWN. West Hartford, Conn.		Oct. 2, 1907
BAKER, PERCIVAL STEVENS. Computer, P. & R. Ry., 65th Ave. and Camac St., Oak Lane, Philadelphia, Pa.	Jun. Assoc. M.	Sept. 4, 1906 Oct. 2, 1907
BANKS, GEORGE HILL. U. S. Engr. Office, Houghton, Mich.		Sept. 4, 1907
BERGENDAHL, GUSTAVE STORM. 1430 Syndicate Trust Bldg., St. Louis, Mo.		April 3, 1907
BERGER, JOHN. 335 Madison Ave., Room 1136, New York City		Oct. 2, 1907
CARVER, GEORGE PAYSON. 53 State St., Boston, Mass.		Oct. 2, 1907
DIEDEN, GOTTHARD VINCENT. Malmo, Sweden.		Oct. 2, 1907
FUCIK, EDWARD JAMES. 813 So. Sawyer Ave., Chicago, Ill.		Oct. 2, 1907

ASSOCIATE MEMBERS (*Continued*).

		Date of Membership.
GANDOLFO, JOSEPH HARRINGTON. Asst. Constr. Engr. with John Van Vleck, 100 Broadway, New York City		Oct. 2, 1907
GUNDERSEN, AUGUST. 605 Whitney Bldg., Detroit, Mich		Oct. 2, 1907
HARPS, HARRY MACY. With Herbert C. Keith, Cons. Engr., 116 Nassau St., New York City	Jun.	Mar. 3, 1903
	Assoc. M.	Oct. 2, 1907
HOPKINS, NEWTON FISHER. 900 Lewis Bldg., Pittsburg, Pa.		Oct. 2, 1907
HORNE, HAROLD WELLINGTON. Cornwall-on-Hudson, N. Y.		Oct. 2, 1907
LEONARD, CLIFFORD MILTON. 1429 Monadnock Blk., Chicago, Ill.		Oct. 2, 1907
MANSFIELD, ROYAL JOHN. Structural Engr., Atlantic, Gulf & Pacific Co., Manila, Philippine Islands	Jun.	Dec. 2, 1902
	Assoc. M.	July 10, 1907
MEANS, THOMAS HERBERT. Fallon, Nev.		July 10, 1907
MEYERS, CLARENCE WILLIAM. Asst. Engr., Rapid Transit Subway Constr. Co., 314 Riverside Drive, New York City	Jun.	Sept. 1, 1903
	Assoc. M.	Oct. 2, 1907
PRESTON, CHARLES HENRY, JR. 24 Wyman St., Waterbury, Conn.		Oct. 2, 1907
SEKIBA, SHIGEKI. Penn Bridge Co., Beaver Falls, Pa.		Oct. 2, 1907
SKINNER, FREDERICK GARDINER. 41 Willis Ave. West, Detroit, Mich.		Sept. 4, 1907
SOLOMON, GABRIEL ROBERTS. 1622 Candler Bldg., Atlanta, Ga.		Oct. 2, 1907
STEVENSON, WILLIAM LAWRIE. 586 Jamestown Ave., Roxborough, Philadelphia, Pa.		Oct. 2, 1907
WARD, CHARLES CLARENCE. P. O. Box 140, Wenatchee, Wash.		July 10, 1907
YATES, EUGENE ADAMS. Asst. Engr., Penn., N. Y. & L. I. R. R. Co., 345 East 33d St., New York City	Jun.	Oct. 3, 1905
	Assoc. M.	Oct. 2, 1907

ASSOCIATE.

COLE, GEORGE NATHAN. 277 Broadway, New York City		Oct. 2, 1907

JUNIORS.

CARTER, LESTER LEVI. Care, Union Constr. Co., Camp D, Vallecito, Cal.		Sept. 3, 1907
COLE, ALDEN BRIGHAM. 56 No. Main St., Carbondale, Pa.		Sept. 3, 1907
CORP, HENRY WILLIAM. 308 Orms St., Providence, R. I.		Oct. 1, 1907
CURTIS, CLINTON ALONZO. Ft. Edward, N. Y.		Oct. 1, 1907
GALVIN, JAMES AUGUSTINE. Barge Canal Office, Mechanicsville, N. Y.		Sept. 3, 1907
KELLEY, MATTHEW DETOBIN. Care, San Juan Light & Transit Co., San Juan, Porto Rico		Sept. 3, 1907
LORD, HAROLD. Office of Light-House Engr., Honolulu, Hawaii		Sept. 3, 1907

JUNIORS (*Continued*).	Date of Membership.
MACKLEM, NORRIS RAYMOND. 615 S. Mechanic St., Jackson, Mich	April 2, 1907
MILLS, ADELBERT PHILO. 40 E. Locust St., Newark, Ohio	Sept. 3, 1907
PAGON, WILLIAM WATTERS. 937 St. Paul St., Baltimore, Md.	Sept. 3, 1907
RICH, WILDER MELOY. 318 Spruce St., E., Sault Ste. Marie, Mich.	Sept. 3, 1907
RINDSFOOS, CHARLES SIESEL. Lock Box 2, Massena, N. Y.	April 2, 1907
TROWBRIDGE, ALFRED LOCKWOOD. Care, J. H. Wise, 925 Franklin St., San Francisco, Cal.	Sept. 3, 1907
YEO, WILLIAM ALBERT. Care, Hudson Companies, 111 Broadway, New York City	Oct. 1, 1907

CHANGES OF ADDRESS.

MEMBERS.

ALBER, HERMANN. 218 Sunset Blvd., Hollywood, Cal.

ANDERSON, JOSHUA THOMAS NOBLE. (Monash & Anderson), 49 Elizabeth St., Melbourne, Victoria, Australia.

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MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(September 11th to October 7th, 1907.)

NOTE.—*This list is published for the purpose of placing before the members of the Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(1) *Journal,* Assoc. Eng. Soc., 31 Milk St., Boston, Mass., 30c.
(2) *Proceedings,* Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal,* Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal,* Western Soc. of Engrs., Monadnock Blk., Chicago, Ill.
(5) *Transactions,* Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly,* Columbia Univ., New York City, 50c.
(7) *Technology Quarterly,* Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator,* Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine,* New York City, 25c.
(10) *Cassier's Magazine,* New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News,* New York City, 15c.
(14) *The Engineering Record,* New York City, 12c.
(15) *Railroad Gazette,* New York City, 15c.
(16) *Engineering and Mining Journal,* New York City, 15c.
(17) *Street Railway Journal,* New York City, 10c.
(18) *Railway and Engineering Review,* Chicago, Ill., 10c.
(19) *Scientific American Supplement,* New York City, 10c.
(20) *Iron Age,* New York City, 10c.
(21) *Railway Engineer,* London, England, 25c.
(22) *Iron and Coal Trades Review,* London, England, 25c.
(23) *Bulletin,* American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal,* New York City, 10c.
(25) *American Engineer,* New York City, 20c.
(26) *Electrical Review,* London, England.
(27) *Electrical World,* New York City, 10c.
(28) *Journal,* New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal,* Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique,* Brussels, Belgium.
(31) *Annales de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand,* Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux,* Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil,* Paris, France.
(34) *Portefeuille Economiques des Machines,* Paris, France.
(35) *Nouvelles Annales de la Construction,* Paris, France.
(37) *Revue de Mécanique,* Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways,* Paris, France.
(40) *Railway Age,* Chicago, Ill., 10c.
(41) *Modern Machinery,* Chicago, Ill., 10c.
(42) *Proceedings,* Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées,* Paris, France.
(44) *Journal,* Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals,* Scranton, Pa., 20c.
(46) *Scientific American,* New York City, 8c.
(47) *Mechanical Engineer,* Manchester, England.
(48) *Zeitschrift,* Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeitschrift für Bauwesen,* Berlin, Germany.
(50) *Stahl und Eisen,* Düsseldorf, Germany.
(51) *Deutsche Bauzeitung,* Berlin, Germany.
(52) *Rigasche Industrie-Zeitung,* Riga, Russia.
(53) *Zeitschrift,* Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.
(54) *Transactions,* Am. Soc. C. E., New York City, $5.

(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
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(62) *Industrial World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
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(78) *Beton und Eisen*, Vienna, Austria.
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(84) *Le Ciment*, Paris, France.
(85) *Proceedings*, Am. Ry. Eng. and M. of W. Assoc., Chicago, Ill.
(86) *Engineering and Contracting*, Chicago, Ill.
(87) *Roadmaster and Foreman*, Chicago, Ill., 10c.
(88) *Bulletin* of the International Ry. Congress Assoc., Brussels.

LIST OF ARTICLES.

Bridge.

The Distribution of Stress in Rivetted Connections.* C. R. Young, S. Can. Soc. C. E. (5) Vol. 20, Pt. 2.
The Durability of Wire Rope under Severe Conditions.* T. H. Schwitzer, Stud. Can. Soc. C. E. (5) Vol. 20, Pt. 1.
The Quebec Bridge Disaster.* (11) Sept. 6; (13) Sept. 12; (12) Sept. 6.
The Quebec Bridge.* Frank W. Skinner, M. Am. Soc. C. E. (11) Sept. 13.
The Erection of the Las Vacas Viaduct.* (14) Sept. 14.
The Substructure of the Dearborn Street Bridge, Chicago.* (14) Sept. 14.
The Collapse of the Quebec Bridge. Frank W. Skinner, M. Am. Soc. C. E. (11) Sept. 20.
The Suspended Falsework of the Cantilever Arms of the Quebec Bridge.* (14) Sept. 21.
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The Erection of the South Cantilever Arm of the Quebec Bridge.* (14) Sept. 28.
The Melwood Avenue Retaining Wall, Pittsburg.* (14) Sept. 28.
Imperfect Butt-Joints in Columns and Stresses in Lattice-Bars.* Henry S. Prichard, M. Am. Soc. C. E. (13) Oct. 3.
La Catastrophe des Ponts-de-Cé (Maine-et-Loire).* Jean Phizen. (33) Sept. 14.
Strassenbrücke in Eisenbeton über die Rixdorf-Mittenwalder Kleinbahn.* Wüg. (51) Aug. 28.
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Brückenbauprojekt Rieden-Sauterach über die Bregenzer Ach.* M. Heimbach. (78) Sept.

Electrical.

Polyphase Systems of Generation, Transmission and Distribution.* M. A. Sammett A. M. Can. Soc. C. E. (5) Vol. 20, Pt. 2.
The Application of the Storage Battery to Lighting, Power and Railway Service.* J. M. S. Waring. (4) Aug.
Fractional Pitch Windings for Induction Motors.* C. A. Adams, W. K. Cabot, and G. Æ. Irving, Jr. (42) Aug.

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Electrical—(Continued).

Electrical Developments in Rio de Janeiro.* (26) Sept. 6.
A Method of Determining the Leading Dimensions of Large and High-Speed Continuous Current Dynamos.* H. M. Hobart. (26) Serial beginning Sept. 6.
Electric Cranes. H. H. Broughton. (73) Serial beginning Sept. 6.
Mechanical Action of Currents on Conductors.* P. Bary. (Tr. from *L'Eclairage Electrique.*) (73) Sept. 6.
Mercurous Sulphate, Cadmium Sulphate and the Cadmium Cell.* G. A. Hulett. (From the *Physical Review.*) (73) Sept. 6.
Insurance and Inspection of Electrical Machinery.* (47) Sept. 7.
Recent Advances in Artificial Lighting.* (13) Sept. 12.
Forces in the Interior of an Electric Conductor.* Edwin F. Northrup. (Abstract of paper read before the Amer. Physical Soc.) (73) Sept. 13.
The Design of Transformers as Influenced by the Employment of Alloy-Sheets.* Robert Pohl. (Abstracted from the *Elektrotechnische Zeitschrift.*) (73) Sept. 13.
Abnormal Primary Current and Second Voltage on Placing a Transformer in Circuit.* Trygve Jensen. (27) Sept. 14.
Switchboard Connections of Wattmeters and Watt-Hour Meters for Measuring Power and Energy in Polyphase Circuits.* Paul MacGahan. (27) Sept. 14.
The Poulsen Arc as a Means of Obtaining Continuous Electrical Oscillations.* J. A. Fleming. (Abstract of a paper read before the Physical Soc.) (73) Sept. 20.
The Electric Elevator Equipment for a Tall Office Building.* (14) Sept. 21.
The Design of Plunger Magnets.* C. P. Nachod. (27) Sept. 21.
On the Elementary Theory of Electric Oscillators.* J. A. Fleming. (73) Sept. 27.
Resistance Coils and Comparisons.* C. V. Drysdale. (Paper read before the Brit. Assoc.) (73) Sept. 27.
Wireless Telephony for the United States Navy.* Herbert T. Wade. (46) Sept. 28.
Elements of Electrical Engineering.* A. E. Watson. (19) Serial beginning Sept. 28.
The Tofwehult-Westerwik Transmission System, Sweden.* Arvid Westerberg. (27) Sept. 28.
Magnetic Hysteresis Phenomena.* M. O. Bloser. (27) Sept. 28.
Tension and Sag in Wire Spans.* Harold Pender. (27) Sept. 28.
Electro-Magnets for Lifting and Handling Materials.* Charles R. Benjamin. (10) Oct.
The Hydro-Electric Plant of the West Kootenay Power & Light Co., Ltd.* (14) Oct. 5.
The New Power Plant of the Lowell Electric Light Corporation.* (27) Oct. 5.
System at Minneapolis for Distributing the Energy Transmitted from Taylor's Falls.* (27) Oct. 5.
Wiring and Connections for Constant Potential Transformers.* Geo. A. Burnham. (27) Oct. 5.
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Das Heylandsche Verfahren zum Anlassen und Regulieren und zur Kompensation der Phasenverschiebung von Induktionsmotoren.* Friedrich G. Wellner. (Paper read before the Dresdener Elektrotechnische Verein.) (48) Sept. 7.

Marine.

The Electrical Plant and Means of Interior Communication of a Modern Ocean-Going Passenger and Cargo Vessel.* Chas. J. Dougherty. (2) July.
Explosive-Mixture Motors.* Commander A. B. Willits. (Abstract from the *Journal* of the Amer. Soc. of Naval Engrs.) (12) Serial beginning Sept. 13.
Design and Arrangement of Marine Turbines and Propellers. Ernest N. Janson. (Paper read before the Amer. Soc. of Naval Engrs.) (47) Sept. 14.
The Electrical Equipment of the SS. *Mauretania.* (73) Serial beginning Sept. 27.
Superheating in Marine Practice.* (47) Serial beginning Sept. 28.
Le Paquebot à Turbines *Lusitania* de la Compagnie Cunard.* L. Piaud. (33) Serial beginning Sept. 21.

Mechanical.

Heating and Ventilation of St. Paul's Hospital, Montreal, Que.* Allan G. McAvity, S. Can. Soc. C. E. (5) Vol. 20, Pt. 1.
The Development of Electricity in the Iron and Steel Industries.* D. Selby Bigge. (71) Vol. 73.
An Investigation on the Use of Steam in Gas-Producer Practice.* William Arthur Bone and Richard Vernon Wheeler. (71) Vol. 73.
Sentinel Pyrometers and their Application to the Annealing, Hardening, and General Heat Treatment of Tool Steel.* Harry Brearley and F. Colin Moorwood. (71) Vol. 73.
Induced Draught, with Hot Air Economisers for Steel-Works and Blast-Furnace Boilers.* A. J. Capron. (71) Vol. 73.
Notes on the Use of Producer Gas for Power Purposes.* J. R. Bibbins. (2) July.
Western Ways in American Gas Business.* Archibald S. B. Little. (66) Sept. 3.
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THE REINFORCED CONCRETE WORK OF THE McGRAW BUILDING.

By William H. Burr, M. Am. Soc. C. E.

To be Presented November 20th, 1907.

The McGraw Building is a true reinforced concrete structure—the latest type of buildings of that general class. It is on the north side of West Thirty-ninth Street, between Seventh and Eighth Avenues, in the City of New York, in that district which has already felt the stimulating influence of the new Pennsylvania Railroad Station in process of construction a half dozen blocks to the south. This part of the city is undoubtedly destined to become a great business center, where substantial buildings of the highest type will be required in order to meet the demands of the development of that vicinity.

The building has a frontage of 126.3 ft. on Thirty-ninth Street, and a depth of 90 ft. It has eleven stories, and a penthouse, or roof structure, nearly equivalent to another floor. The height of the roof is 145 ft. above the ground floor, or nearly 150 ft. above the street, or, finally, 159 ft. 6 in. above the basement floor. While, therefore, it is far from ranking among the tallest sky-scrapers of the city, it is to be classed among the high business buildings of Manhattan Island. Its

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.



THE MCGRAW BUILDING

height is much greater than has heretofore been considered practicable for a purely reinforced concrete building, *i. e.*, a concrete building without iron or steel columns.

It has been constructed for the McGraw Realty Company primarily to accommodate the business of the McGraw Publishing Company, whose publications include *The Engineering Record, Electrical World, Street Railway Journal* and the *Electro-Chemical* and *Metallurgical Industries.* At the same time, it was designed to accommodate not only the printing presses of the McGraw Publishing Company, but any other similar business requiring the operation of heavy machinery or the storage of heavy goods in bulk. It was imperatively necessary, therefore, that the building should be designed and built so as to afford the greatest possible resistance to the vibration of heavy machinery, and possess to an unusual degree both rigidity and durability. It is also fire-proof to such an extent that the McGraw Realty Company may reasonably be its own insurer. While the building is admirably adapted to office use, its lower floors, particularly, are thus capable of affording provision for those business purposes which require heavy and substantial construction.

Like most other portions of that part of the city north of Fourteenth Street, the rock originally at the site of the building was close to the surface. The excavations for the foundation were not carried deeper than about 20 ft. below the street surface, and there the entire foundation was placed upon the gneiss which forms the ledge or bed-rock. There were no real foundation problems to be solved. The columns supporting the building, and the retaining or area walls around the basement, were all founded upon the same ledge, under the requirements of the Building Code of the City of New York.

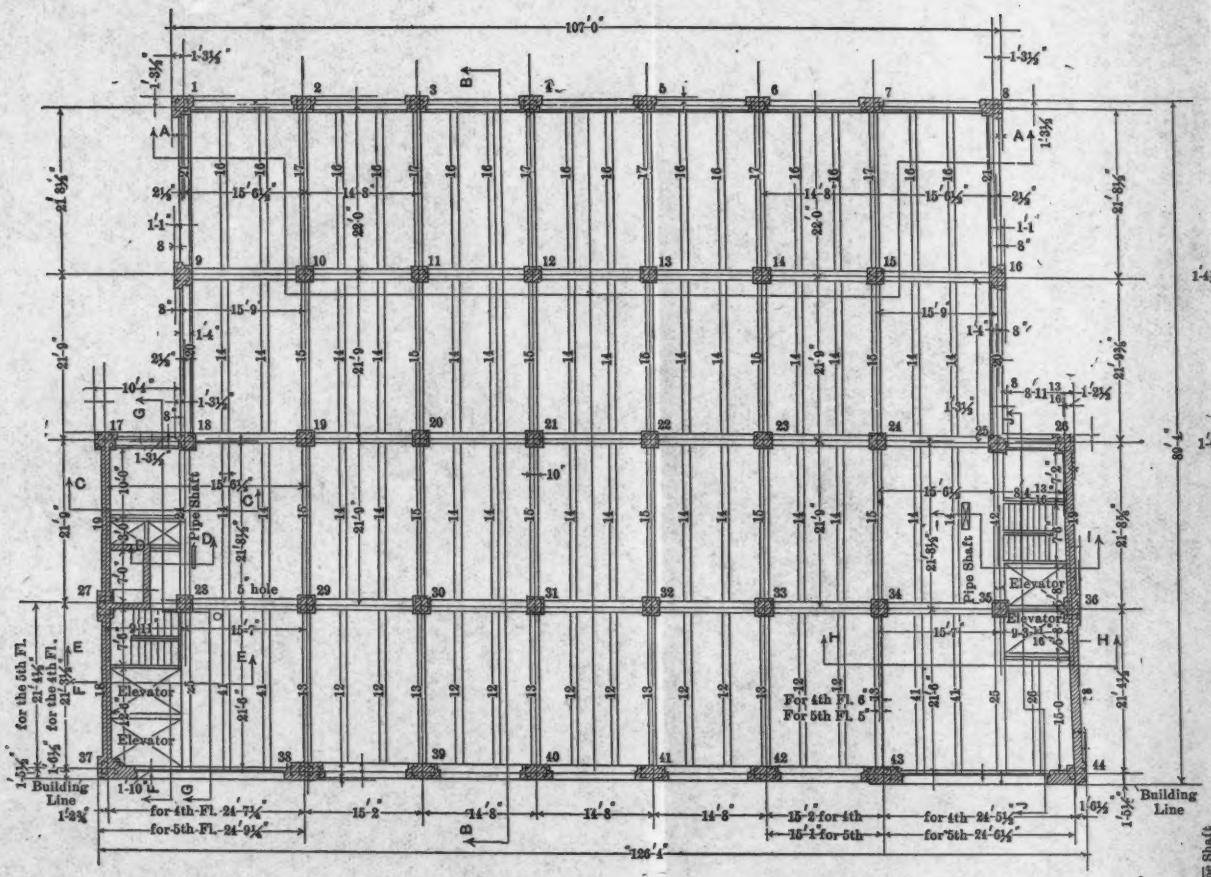
In order to meet the exacting requirements for the unusually substantial structure required by the McGraw Publishing Company, it was decided to design the building for a live load of 250 lb. per sq. ft. for the first and second floors, 200 lb. per sq. ft. for the third floor, 150 lb. per sq. ft. for the fourth floor and 125 lb. per sq. ft. for all the other floors above the fourth, and with a live load of 60 lb. per sq. ft. for the roof. All parts of the floor beams and girders, therefore, and the columns, were designed to sustain, under the requirements of the Building Code, the actual weight of the structure and the live load specified above.

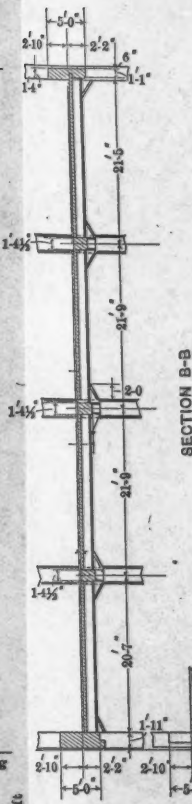
Prior to the submission of this design, the Building Code of the City of New York had permitted a working stress of only 350 lb. per sq. in., for concrete in direct compression, it being practically assumed that all reinforced concrete columns would be of the Considère type. Obviously, if this regulation should prevail for an eleven-story building, the size of the columns in the basement and lower stories would be so great as to trench too seriously upon the available space for machinery or for other business purposes. As it was strongly desired to secure all the material advantages accruing to reinforced concrete structures, it became necessary to design such columns as would be of much smaller cross-section than those of the type heretofore prevailing. Two procedures were available: one was to use a substantial quantity of steel in the form of an ordinary steel column suitably designed for this purpose, and the other was to use the concrete in such a way as to justify a much larger working stress per square inch than that prescribed in the Building Code. These requirements are met in an eminently satisfactory way by the columns of the type used. All columns throughout the building are composed of an interior filling of concrete combined with steel angles latticed in the ordinary manner of built steel columns. The interior columns and most of those in the exterior walls are built with four angles, with the usual riveted lattice or lacing bars on the four sides of each column. In the case of a number of the exterior columns it was necessary, for the attainment of unavoidable structural ends, to use a column of elongated cross-section with eight steel angles of the same general type as those in the interior, which, with the concrete filling, form a column of two cells, so to speak, rather than one. The plans accompanying this paper (Plates XCI to XCIV) show fully and clearly this arrangement of the combined concrete with steel angles and lacing bars. In all cases the steel angles, with the corners of the angles turned out, were spaced as far apart as the extreme outer dimensions of the completed column would permit.

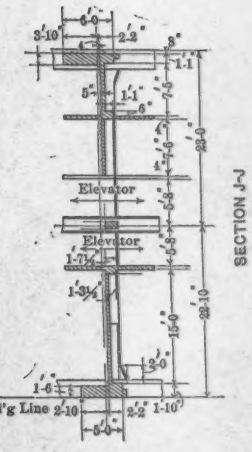
In accordance with the requirements of the Building Code, there is a thickness of 2 in. of concrete outside of the steel angles. This 2-in. shield of concrete is assumed to carry no load whatever; its function is simply that of fire-proofing, *i. e.*, to protect the steel against the immediate heat or flames of any fire that may start in the combustible materials at any time stored in the building, or of a conflagration in

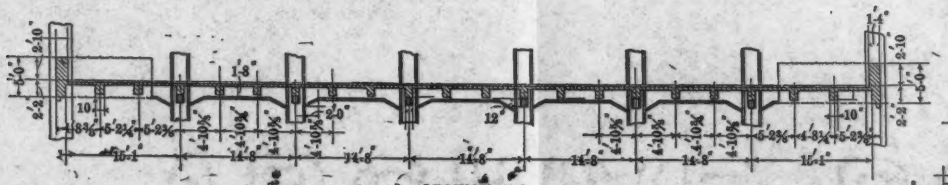
GENERAL PLAN OF FLOOR ARRANGEMENTS AND COLUMN LOCATIONS WITH TYPICAL FLOOR SECTIONS.

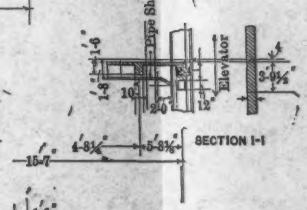
Mc GRAW BUILDING
NEW YORK CITY

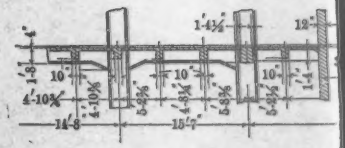


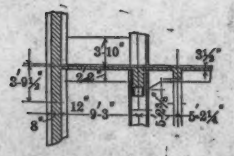


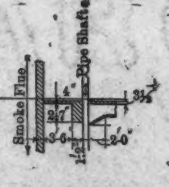


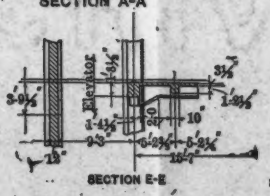


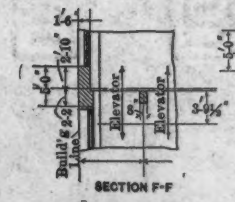


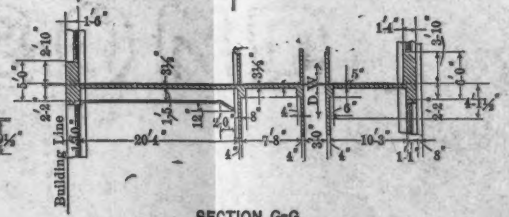


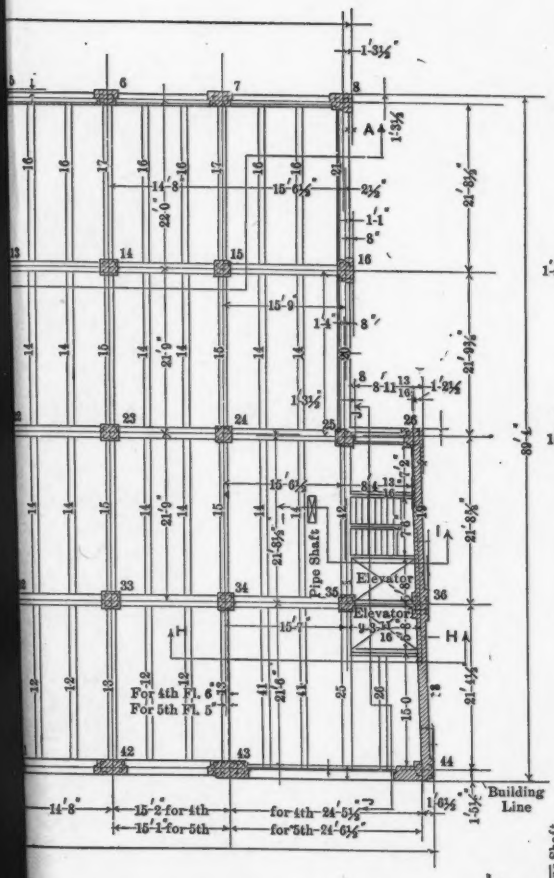


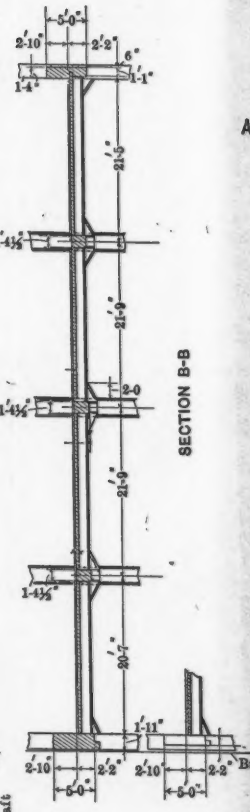


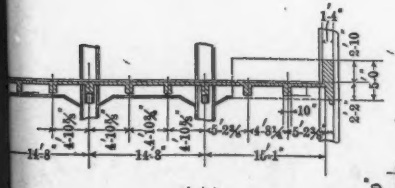


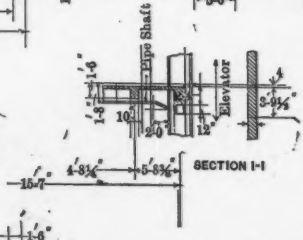


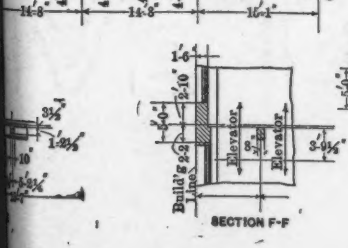


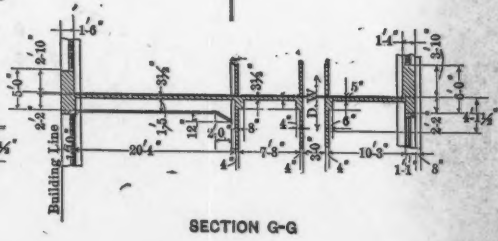

For 4th Fl. 6"
For 5th Fl. 5"
Pipe Shaft
Elevator
Elevator
Building Line
14'-8"
15'-2" for 4th
15'-1" for 5th
for 4th 24'-6½"
for 5th 24'-6½"


SECTION B-B
Build'g Line



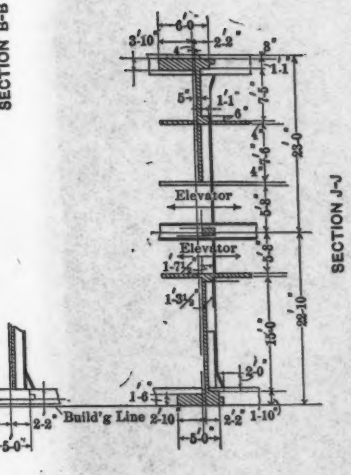

Pipe Shaft
Elevator
SECTION I-I

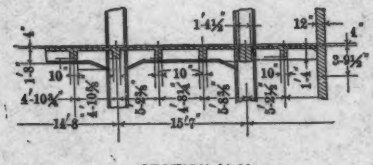

Build'g Line
Elevator
Elevator
SECTION F-F


Building Line
D.V.
SECTION G-G

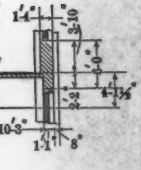
GENERAL PLAN OF FLOOR ARRANGEMENTS AND COLUMN LOCATIONS WITH TYPICAL FLOOR SECTIONS.

Mc GRAW BUILDING
NEW YORK CITY





SECTION H-H





an adjoining building. The concrete within the exterior dimensions or outline of the steel angles is available for carrying a compressive or column load. As it is completely embraced or surrounded by the steel angles and lacing bars, it is steel "banded" in the most effective manner possible. Its enclosure in the steelwork of the column is so rigid, manifestly, that lateral strains under column loads must be greatly reduced—in fact, nearly prevented—within any ordinary limits of loading. Such concrete, therefore, is largely prevented from the usual yielding of that material under compression, and its compressive carrying capacity is increased. This is not only obvious from the condition of the concrete in these columns, but that view is confirmed by the comparatively few results of tests of concrete columns of this character. When, therefore, the plans of these columns were submitted to the Bureau of Buildings of the City of New York for examination and final approval, a special regulation was made permitting the concrete to carry a maximum working load of 750 lb. per sq. in. within the exterior limits of the steel angles, the exterior 2 in. of concrete, as stated previously, being considered simply a fire-protecting shield. This increased permissible load upon the concrete is coupled with the further provision that the cross-section of the steel in any column at any floor shall be sufficient to carry the entire dead load above that section without stressing the steel to more than 16 000 lb. per sq. in.

The use of the steel, in load-supporting condition, as a long column independent of the concrete, and at the same time forming a rigid banding member for the latter, with the consequent increase of permissible working load on the concrete, reduced the size of the columns in the basement and lower stories to dimensions quite consistent with the desired convenient and economical use of the clear floor space. Columns of this general type combine with their high carrying capacity great convenience in erection, for their steel sections may be erected ahead of the concrete work and afford convenient supporting members for the adjoining forms or for other erection work. The lacing bars, rivet heads, and other projecting column details act positively in creating a firm and complete hold or bond between the steelwork of each column and the concrete enclosed within it. This feature of these columns compels the steel and the enclosed concrete to act as a unit, and this action is enhanced by placing all the lacing

bars in one direction inside the steel angles, the other set being placed outside, as shown on the plans.

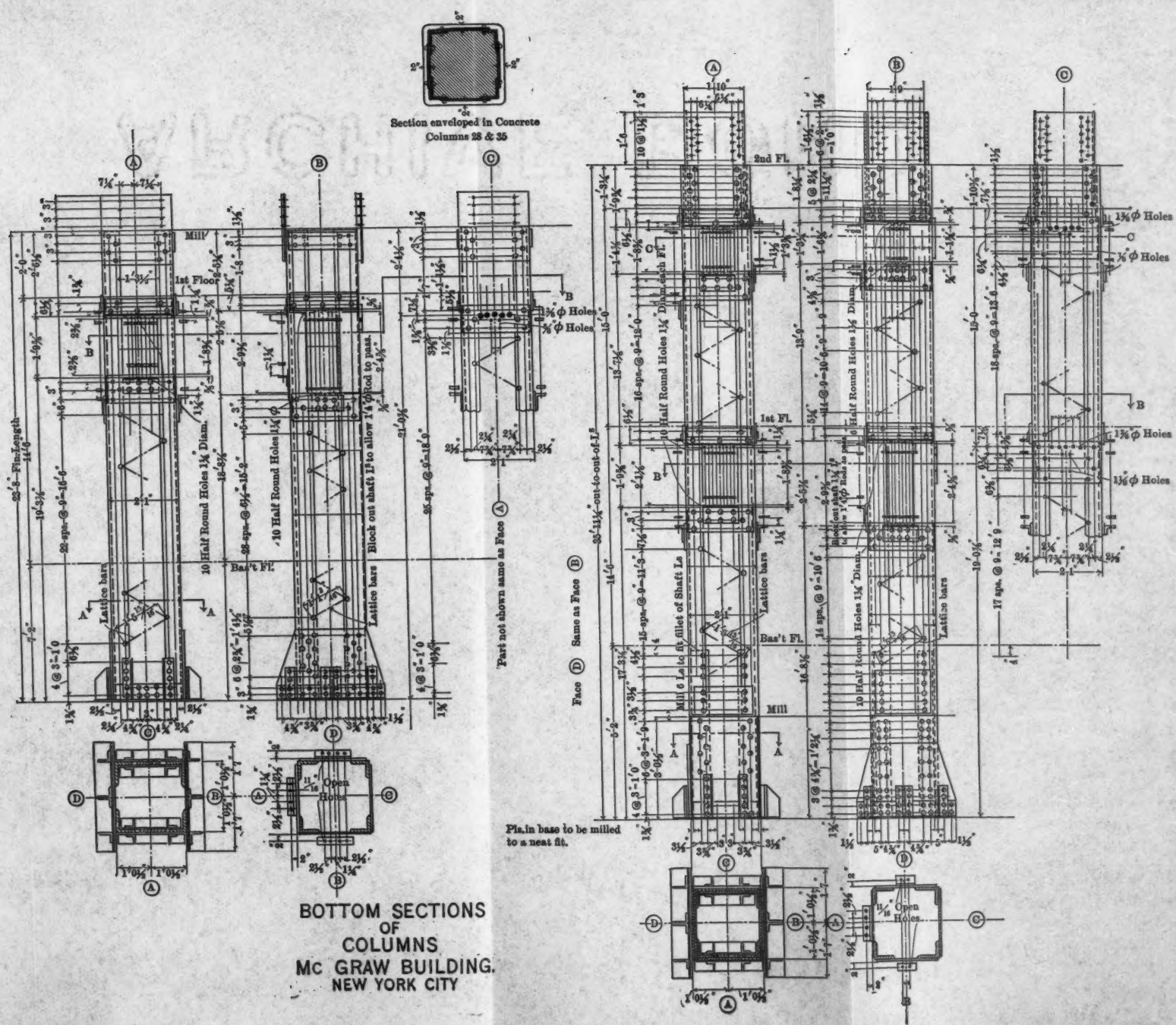
The Building Code requires the ratio between the moduli of elasticity for the steel and concrete to be taken as 12. Hence, as the permissible compressive working stress in the concrete was taken at 750 lb. per sq. in., the corresponding working stress in the steel would be 9 000 lb. per sq. in.

The largest columns (in the basement) have exterior dimensions of 29 by 29 in., but, at the eleventh story, the exterior dimensions are reduced to 14 by 14 in. These columns were built in sections of a length equal to the combined height of two stories, *i. e.*, 25 ft. The extra metal involved in this procedure was too small to be of practical consequence, and the expense of half the joints, if a change of section had been made at every floor, was saved. Much time was also gained in the erection of the steelwork. The abutting ends of the column sections were faced, and the joints were made by suitable splice-plates. Where there was a change in the exterior dimensions of the steelwork, full-strength splices were made by riveting suitable short-angle sections on the interior of the splice-plates of the lower part of the joint. These details are also shown on the plans.

The ratio of the area of steel section to that of the concrete for the various columns varied from 10% in the basement, where the steel carries about 57% of the total load, to 3½% in the ninth floor, where 30% of the total load is carried by the steel. The requirements of the Building Code for a design of this type raises the percentage of steel to much higher values than in ordinary concrete-steel work.

Table 1 shows the number and sizes of steel angles used throughout the main columns of the building.

The design of the floors, in general, is quite similar to that usually found in buildings of this class, although there are certain important details which do not come under that observation. As the plans indicate, the spacing of the columns is such as generally to divide each floor into panels 21 ft. 9 in. by 14 ft. 8 in. between centers of columns, the clear span of the main girders between columns being 14 ft. 8 in. less the width or diameter of the column section. The clear span of the floor beams between the main girders is 21 ft. 9 in. less the width of these girders. These prevailing lengths of spans of the beams and girders were modified at a few points in each floor to accommodate



BOTTOM SECTIONS
OF
COLUMNS
Mc GRAW BUILDING.
NEW YORK CITY



TABLE 1.—Number and Sizes of Steel Angles Used in the Main Columns of the McGraw Building.

Floor.	Sizes of Steel Angles in Columns, and outside dimensions of Steel Columns, *i. e.*, back to back of Angles.			
11....	4 L's, $2\frac{1}{2}$ by $2\frac{1}{2}$ by $\frac{5}{16}$ in. 10 by 10 in., b. to b.	4 L's, $3\frac{1}{2}$ by $3\frac{1}{2}$ by $\frac{5}{16}$ in. 10 by 10 in., b. to b.	4 L's, $2\frac{1}{2}$ by $2\frac{1}{2}$ by $\frac{5}{16}$ in. 12 by 26 in., b. to b.	4 L's, $2\frac{1}{2}$ by $2\frac{1}{2}$ by $\frac{3}{8}$ in. 12 by 26 in., b. to b.
10....	4 L's, 3 by 3 by $\frac{7}{16}$ in. 17 by 17 in., b. to b.	4 L's, $3\frac{1}{2}$ by $3\frac{1}{2}$ by $\frac{5}{16}$ in. 10 by 10 in., b. to b.	4 L's, 3 by 3 by $\frac{7}{16}$ in. 12 by 26 in., b. to b.	4 L's, $2\frac{1}{2}$ by $2\frac{1}{2}$ by $\frac{3}{8}$ in. 12 by 26 in., b. to b.
9....	4 L's, 3 by 3 by $\frac{7}{16}$ in. 17 by 17 in., b. to b	4 L's, $3\frac{1}{2}$ by 3 by $\frac{5}{8}$ in. 17 by 17 in., b. to b.	4 L's, 3 by 3 by $\frac{7}{16}$ in. 12 by 26 in., b. to b.	4 L's, 3 by 3 by $\frac{9}{16}$ in. 12 by 27 in., b. to b.
8....	4 L's, 5 by 3 by $\frac{11}{16}$ in. $18\frac{1}{2}$ by $18\frac{1}{2}$ in., b. to b.	" " " " " "	4 L's, $3\frac{1}{2}$ by 3 by $\frac{5}{8}$ in. 12 by 28 in., b. to b.	" " " " " "
7....	" " " " " "	4 L's, 6 by 4 by $\frac{3}{4}$ in. $18\frac{1}{2}$ by $18\frac{1}{2}$ in., b. to b.	" " " " " "	4 L's, $3\frac{1}{2}$ by $3\frac{1}{2}$ by $\frac{11}{16}$ in. 12 by 29 in., b. to b.
6....	4 L's, 6 by 4 by $\frac{13}{16}$ in. $20\frac{1}{2}$ by $20\frac{1}{2}$ in., b. to b.	" " " " " "	4 L's, 5 by $3\frac{1}{2}$ by $\frac{5}{8}$ in. 12 by $30\frac{1}{2}$ in., b. to b.	" " " " " "
5....	" " " " " "	4 L's, 6 by 6 by $\frac{13}{16}$ in. $20\frac{1}{2}$ by $20\frac{1}{2}$ in. b. to b.	" " " " " "	4 L's, 5 by $3\frac{1}{2}$ by $\frac{11}{16}$ in. 16 by 32 in., b. to b.
4....	4 L's, 6 by 6 by $\frac{7}{8}$ in. 22 by 22 in., b. to b.	" " " " " "	4 L's, 6 by 4 by $\frac{11}{16}$ in. 16 by $33\frac{1}{2}$ in., b. to b.	" " " " " "
3....	" " " " " "	4 L's, 8 by 6 by $\frac{7}{8}$ in. 22 by 22 in., b. to b.	" " " " " "	4 L's, 6 by 4 by $\frac{13}{16}$ in. 16 by 35 in., b to b.
2....	4 L's, 8 by 6 by 1 in. 24 by 24 in., b. to b.	" " " " " "	4 L's, 6 by 4 by $\frac{7}{8}$ in. 16 by $36\frac{1}{2}$ in., b. to b.	" " " " " "
1....	" " " " " "	4 L's, 8 by 6 by 1 in. 25 by 25 in., b. to b.	" " " " " "	4 L's, 6 by 4 by $\frac{15}{16}$ in. 16 by 38 in., b. to b.
Basement....	4 L's, 8 by 6 by 1 in. 25 by 25 in., b. to b.	" " " " " "	4 L's, 6 by 4 by $\frac{15}{16}$ in. 16 by 38 in., b. to b.	" " " " " "

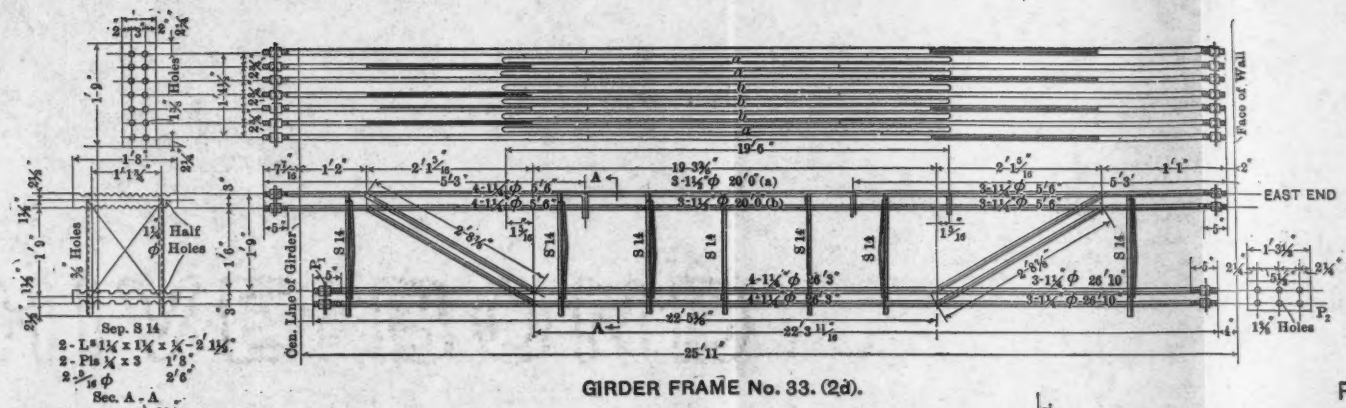
such features of construction or details of floor space as stairways, elevator shafts, and similar details.

As the plans indicate, all floor-girder and beam reinforcement was of round steel rods, of sizes running generally from $\frac{3}{4}$ in. to $1\frac{3}{8}$ in. in diameter. These rods were grouped in one plane on the tension side of each beam or girder. As a rule, every alternate rod was bent upward at the end of each span so as to rise within about 2 in. of the top of the concrete, from which point it continues through either the main girder or the adjoining column, as the case may be, into the adjoining span well toward the quarter point of the latter. By these means, true continuity of beams and girders was secured in every case. In addition to this, the end of each rod was bent down, forming a right-angled turn, with an arm from 2 to 3 in. long, thus insuring a rigid bond or connection with the concrete. This main detail, formed by carrying the rods through the girders and columns, is an important feature in securing continuity and rigidity in the general construction of the building. It is believed to be one of the most important details of the best design of reinforced concrete building construction, and it should be secured either in the manner adopted in this building or by some other procedure of at least equal excellence.

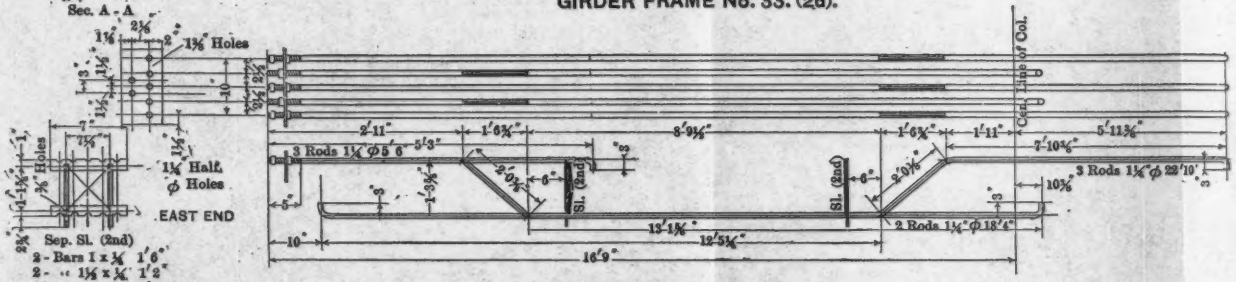
The proper spacing of these reinforcing rods was secured by suitable supporting details throughout the length of the beams and girders themselves and by notches cut in angle-brackets riveted on the columns where they joined the latter members. At the columns, rigidity of connection was secured by bolting clamps through the angle-brackets just named and jamming the rods by tightening the nuts against those brackets. This secured an exceedingly strong metal connection between the reinforcing rods and the steel columns, aside from the further rigidity produced by the concrete mass of the intersecting columns, beams, and girders. These details, shown on the plans, were designed with care for the purpose of securing the strongest possible steel connections between the beams or girders and the columns, it being one of the main purposes to attain rigid continuity between floors and columns, and floors and outside walls. It is believed that unusual stiffness and strength have been given to this building by these means.

All beam and girder computations required by the floor designs were made in accordance with the provisions of the Building Code of the City of New York, the usual common theory of flexure formulas

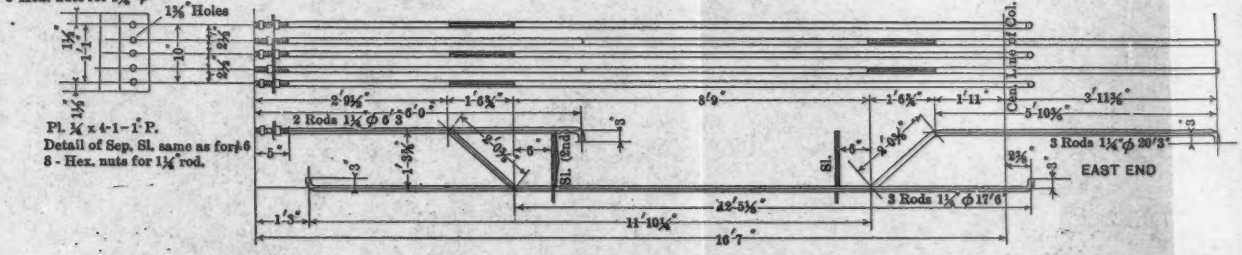
REINFORCING RODS OF SECOND-FLOOR GIRDERS. Mc GRAW BUILDING. NEW YORK CITY



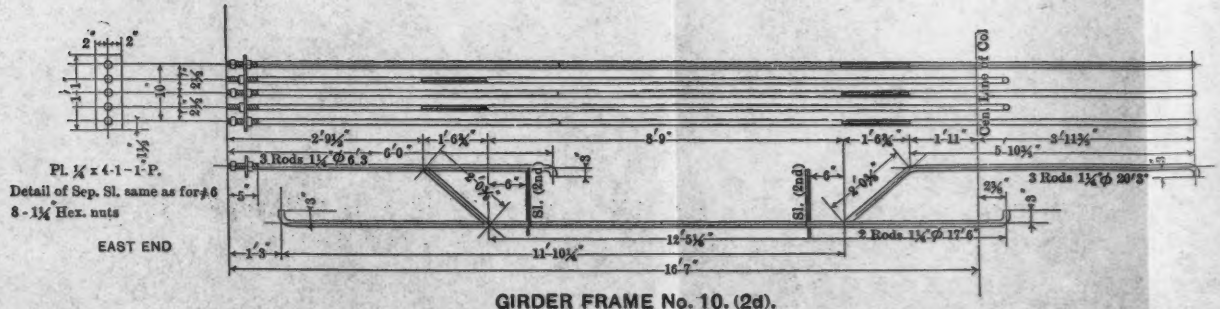
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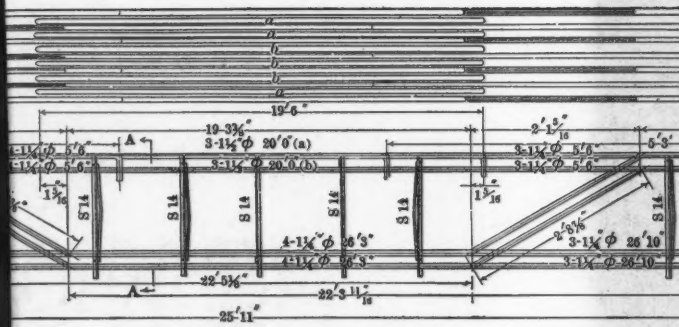
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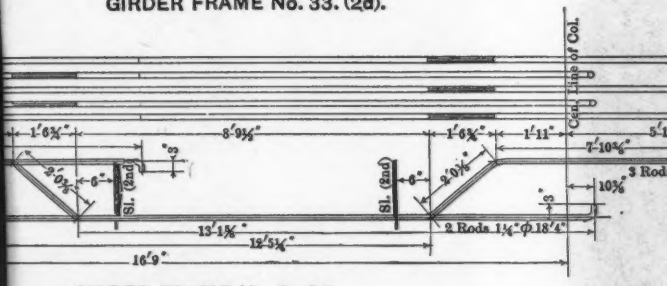
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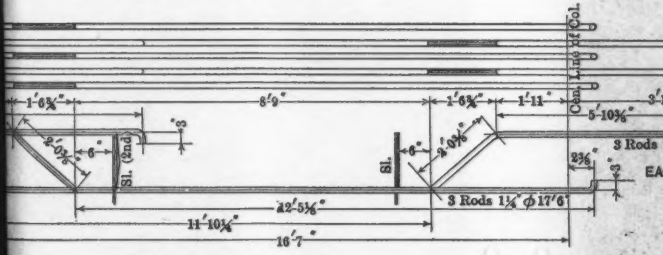
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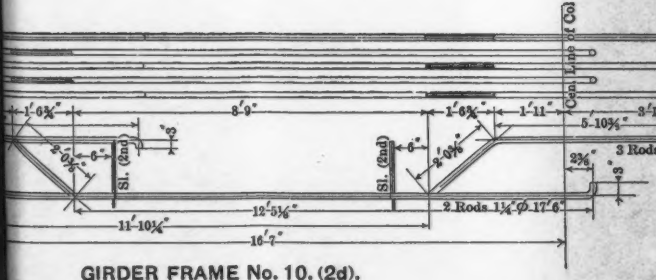
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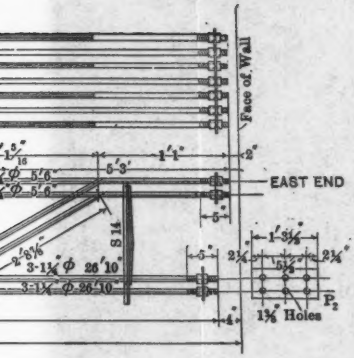
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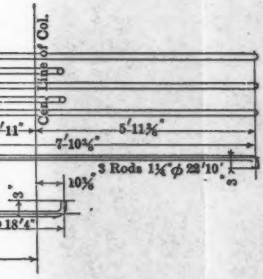


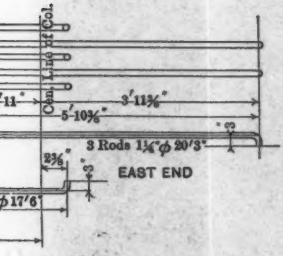
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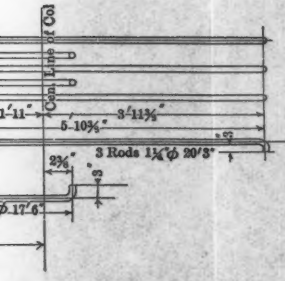


GIRDER FRAME No. 10. (2d).









REINFORCING RODS
OF
SECOND-FLOOR GIRDERS.
Mc GRAW BUILDING.
NEW YORK CITY

for concrete-steel beams being used. While the parabolic law of variation of intensity of stress in concrete beams results in a trifling economy of material, it is less rational and simple than the usual straight-line law of variation, and the latter is more nearly accurate.

The Building Code of New York does not permit the condition of perfect continuity of beams to govern the design of reinforced concrete floor beams and girders. It is permitted, however, to consider the maximum bending moment of such beams, when uniformly loaded from end to end, as the total load multiplied by one-tenth of the span, rather than one-eighth of the span as would be taken were the beams simply supported at each end. This is a widely used method for continuity, in favor of which much can be said. It is extremely doubtful whether perfect continuity is attained in any case, but it is certain that a material advantage is secured over the condition of a beam simply supported at each end. The one-tenth rule, as it may be called, is a reasonable compromise.

Another condition insisted upon in the design of this building was a metallic provision for taking the end shears of beams and girders. By referring to the plans, there will be observed inclined portions of the round steel reinforcing rods to which attention has already been called. In every case there is sufficient steel in these inclined portions of rods to take the total end shears multiplied by the secant of the inclination rods to a vertical line without stressing the steel to an unsafe extent. While the tension in the steel produced in this manner, ignoring entirely the shearing resistance of the concrete, is higher than would normally be prescribed, it is far below the elastic limit, and forms a safe provision for the entire end shear in case any exigency should arise producing such a break in the concrete as practically to destroy its capacity for shearing resistance. In addition to this condition, there is sufficient concrete also at the ends of beam and girder spans to carry the shear at an intensity of 50 lb. per sq. in. of concrete section as permitted by the New York Building Code. This, also, has been considered one of the essential details of a concrete-steel building designed for a heavy and otherwise fatiguing service.

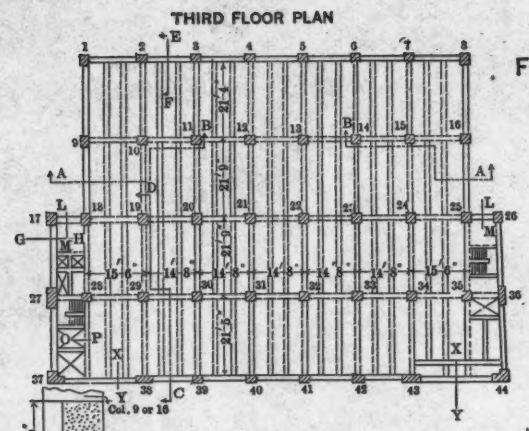
The floor slabs spanning the spaces between the floor beams are 4 in. thick in the lower floors, carrying the heaviest loads, and 3½ in. thick in all the higher floors. Their reinforcements are ½-in. and ⅝-in. rods, long enough to extend over a number of panels or spans so as

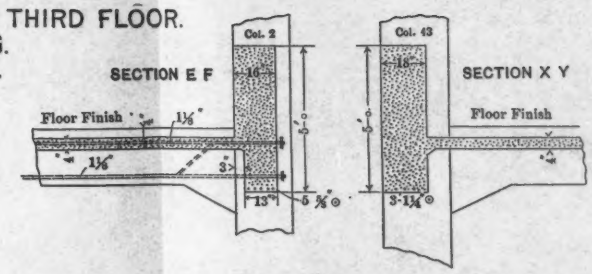
to make these also continuous. Their general design is similar to that of the floor beams and girders. As the distance apart of the centers of the floor beams is about 5 ft. 2 in., the clear span of these floor slabs varies from about 4 ft. to a little more than 4 ft. 4 in., according to the thickness of the adjoining floor beams on either side of the span.

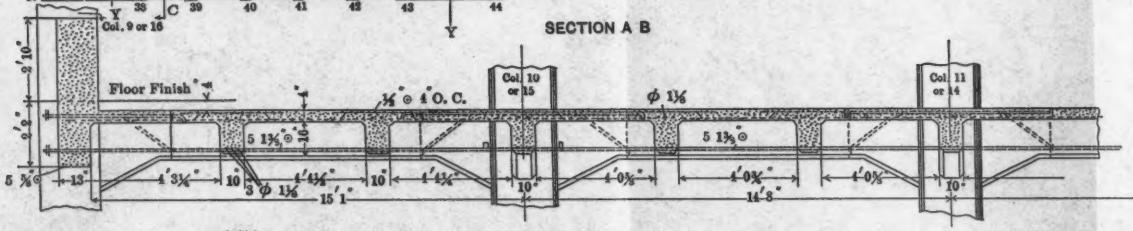
The proper design of the wooden forms or moulds for a concrete-steel building, in order to secure expeditious and economical work, is the most difficult part of the entire undertaking, and the principal improvements to be made in it are those which pertain to perfecting a proper system of construction of the forms and their ready handling. The quantity of lumber required in them, and the carpentry work necessary in making repairs consequent upon their use and re-use for successive floors, and in their supports, constitute far larger items of cost than might at first be supposed. If these costs are to be reduced, as they must be for heavy concrete-steel construction of the best class, the principal study of the engineer must be directed to this particular part of his work. While these ends may not be, and probably have not been, completely attained in this instance, the system of forms used gave excellent results in the quality of the concrete produced, and led to reasonable economy and efficiency. The weight of concrete and the relatively large quantities used in such individual members as beams, girders, and columns make heavy forms imperative and substantial support necessary.

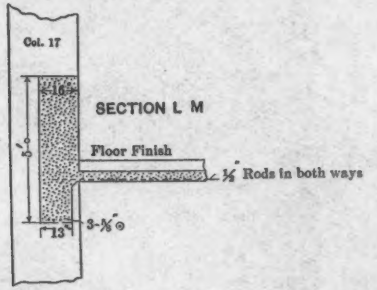
The details of the timber forms for the floor beams and girders where they meet the column forms require especial attention. A proper design of the parts where the floors and columns join will result in great economy in the details of the forms. If the shapes of the exterior surfaces of the concrete are complicated and require careful fittings of the column and floor forms, expensive carpentry work will be required wherever a column pierces a floor, whereas simply shaped concrete surfaces will eliminate that work and greatly expedite the construction. Similarly, it is highly desirable that there shall be as few changes as possible in the exterior dimensions of the columns. If exterior column dimensions could be retained unchanged from basement to roof, it would make possible complete uniformity of the details of column and floor forms throughout the entire building, eliminating a great amount of fitting and carpentry work otherwise unavoidable.

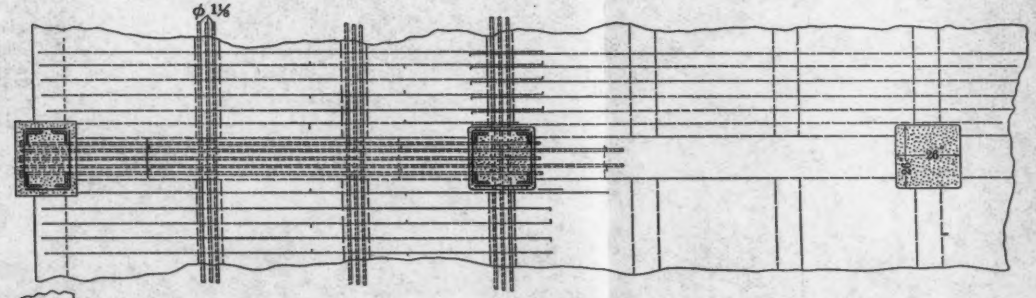
DETAILS OF FLOOR BEAMS AND GIRDERS OF THIRD FLOOR. McGRAW BUILDING. NEW YORK CITY

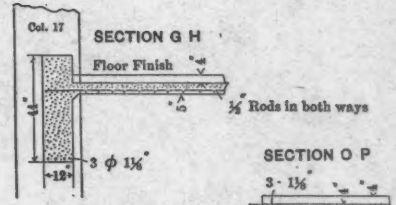


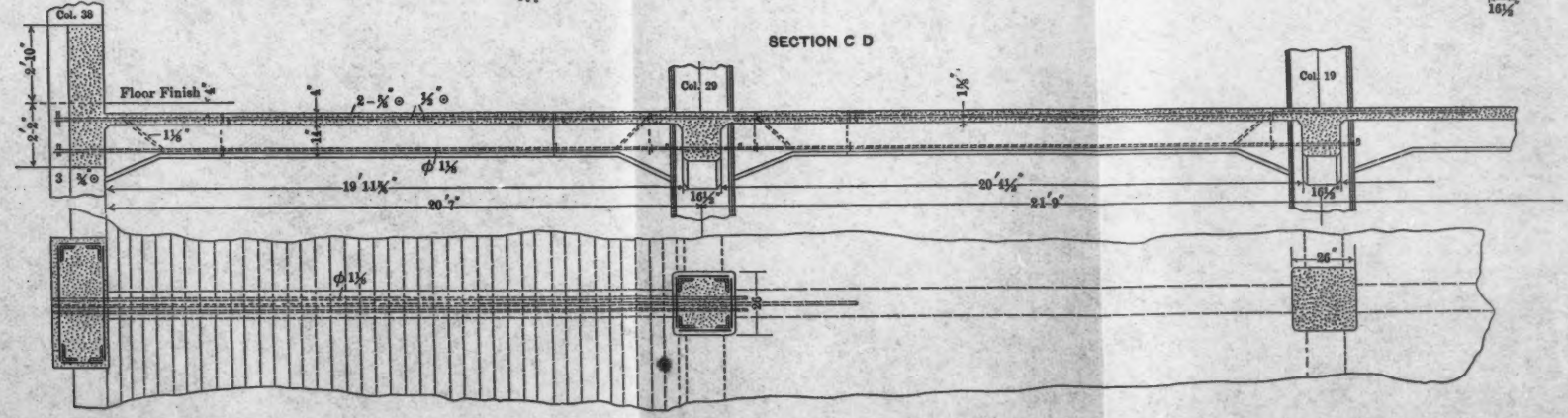












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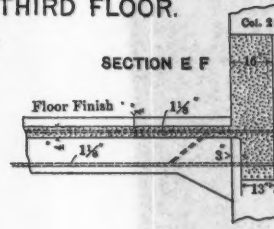
FLOOR BEAMS AND GIRDERS OF THIRD FLOOR.

McGRAW BUILDING.

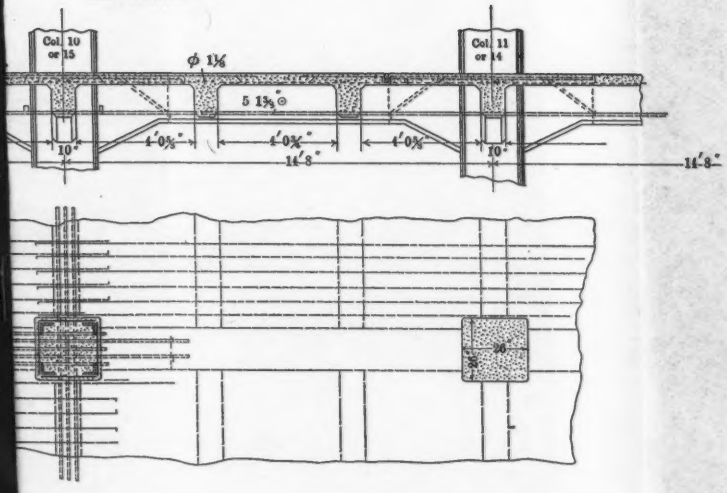
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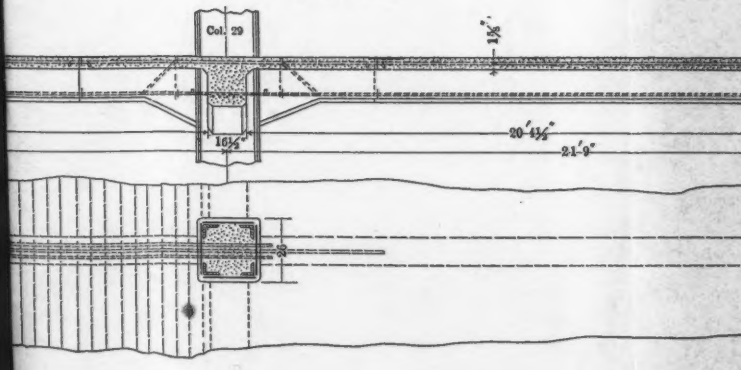
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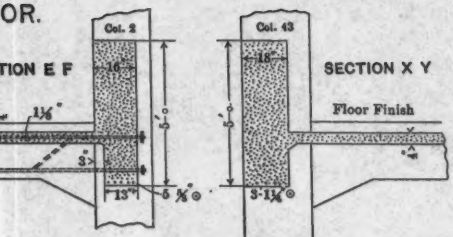


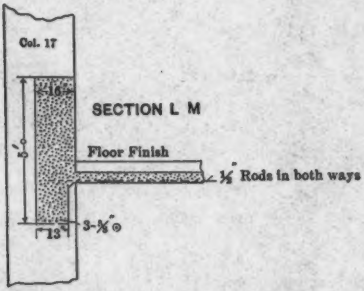
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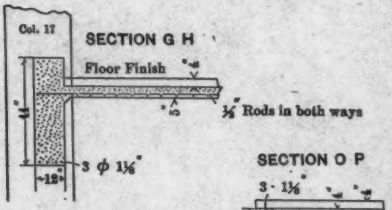
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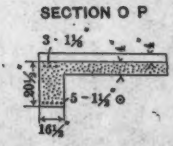
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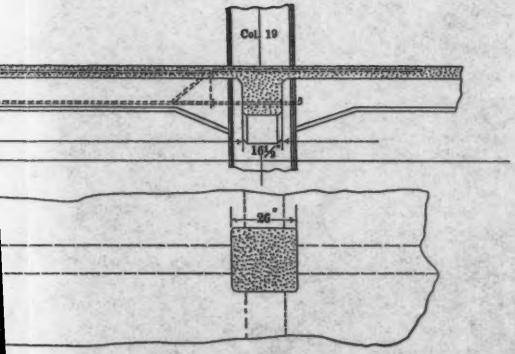




14'-8"







It is obvious that it is essentially impossible to retain uniform exterior column dimensions throughout the series of floors from the bottom to the top of the building, but the most scrupulous care should be exercised to make these changes as few as possible and in such a way as to reduce to the utmost extent changes of details in the forms.

A reference to the plans will show that the floor forms between the beams consisted of large shallow boxes with truncated corners between the sides and the bottom. They were placed bottom up on stable supports and separated by the thickness of the adjoining floor beams at the sides and by the thickness of the main floor girders at their ends. The bottom of the opening between the adjoining sides of any two of them was then suitably closed with planks or boards so that, when the concrete was finally poured over their tops to the thickness of the floor slabs, the desired paneling of those slabs between the beams and girders was secured. It is imperative, for expediting the work, as well as for economy, that these box forms for the floors shall be constructed so that they may be removed readily after the concrete becomes sufficiently hard. To secure this important result, such forms must be readily collapsible at both ends and sides, and, at the same time, they must be substantial enough to hold the wet concrete without distortion and so well made that they may be handled in removing from one floor and replacing on a higher one without sensible damage. This constitutes one of the most essential points in the design of these forms, which, in this case, were collapsible, although perhaps not as freely as might be desired. When the forms stick to the concrete in the process of removal laborers use sledges and iron bars, driving the latter between the new concrete and the forms and making a fulcrum of the former. This results in seriously marring what might otherwise have been a highly satisfactory concrete surface. The same general observations apply to the forms for the columns. Whenever the art of reinforced concrete construction is brought to the high state of excellence which it must ultimately reach through a proper design of the forms, making their erection, support and removal expeditious and free, the labor bills for the work and the repairs of the forms themselves will be so greatly reduced as to give this class of construction material economic advantage.

The length of time which the forms should remain in place supporting fresh concrete will depend on the temperature, and hence on

the season as well as on the character of the work designed. It is clear that, with the substantial steel reinforcement of the columns of this building, a minimum of time would be sufficient for the column forms, but as it was not convenient to remove the latter until the floor forms were also ready to come down they were all kept in place for at least 19 days. Three entire sets of forms for floors and columns were made, so that, while concrete was being poured for the uppermost floor being constructed, the two stories immediately below were still supported by the timber forms. The lowermost set of forms was then taken down and placed above the freshly formed concrete last put in place. In this manner the forms could be left in place long enough to satisfy the requirements of even the winter season.

The concrete work of the building proper was begun in the basement in September, 1906, and the concrete parapet walls on the roof were completed on April 15th, 1907. These dates show that the work was carried on almost uninterruptedly throughout the winter. A few of the coldest and stormiest days of the winter were sufficiently severe to cause the work to be suspended for the day. When it is remembered that from the latter part of January until the early part of March the weather was phenomenally severe, it is demonstrated by actual experience that reinforced concrete building work may be conducted under proper conditions through a New York winter without material interruption.

After the completion of the lower two or three stories, when the organized force had become accustomed to the character of the work and the sequence of operations required, the average rate of progress, including the delays and occasional interruptions caused by the winter weather, was about 12 calendar days to a story.

From the early part of December to the latter part of March the window openings of the story below the floor in process of construction were closed with canvas, behind which, distributed over the entire floor, salamanders burning coke were constantly kept in operation. These salamanders were to some extent concentrated under the freshly poured concrete. By these means entirely satisfactory temperatures could be maintained, so that the retarding influence of the frost on the setting of the concrete was to a great extent eliminated, except for the fact that occasionally the top surface of the fresh concrete was frozen. The warmest air produced by the salamanders would rise to

and remain in the overhead cellular spaces of the timber floor forms and act there with a high degree of efficiency.

In connection with the operation of the salamanders below the fresh concrete, the top of the latter, as fast as poured, was always protected by a covering of hay or canvas, or both. These protective measures were scrupulously enforced throughout the winter with entirely satisfactory results. Indeed, there was no evidence to be found throughout the whole building to show that any part of the concrete whatever was affected injuriously to the slightest extent by the frost. During a considerable portion of the winter a few salamanders were kept burning in the second floor below the work in progress.

All the construction work of the building was carried on from a high central temporary timber tower running from the basement to a height of nearly 75 ft. above the roof. This timber tower was 31 ft. square and built with 10 by 10-in. yellow pine spliced corner posts properly braced. Each 10 by 10-in. corner stick carried a derrick boom 75 ft. in length. These derricks were first placed low down on the tower, and then raised from time to time to elevations required by the progress of the work. The booms were long enough to command the entire area of the work, and had a sufficient swing or reach to pick up material, including sections of the steel columns, delivered in the street in front of the building, and put it in its proper permanent place. The hoisting engines were placed in the basement, and steel cables ran from them up to the derricks.

It was a question at first whether the cost of this tower and derricks was justified by the amount and character of the work to be done, but they were found to be fully justified and well adapted to their purpose. It was probably as economical and expeditious a method as could have been devised for handling the materials and serving the work. As the building was carried up, the work within the limits of the tower was completed, with the exception of the points where the corner 10 by 10-in. sticks pierced the respective floors where enough free room was left for the operating cables. After the concrete work was finished the tower was taken down through the succeeding floors of the building, and the holes left for the corner posts were filled.

There was nothing unusual about the character of the materials used throughout the building. The material and workmanship of all the steelwork were supplied and manufactured under Cooper's Speci-

fications. The Portland cement used was the Dragon Brand, and it was tested and supplied under the standard specifications recommended by the Special Committee of the American Society of Civil Engineers. The sand, broken stone, and gravel were supplied by different parties about the City of New York. Some of the broken stone came from the north, down the Hudson River, and most of the sand and gravel came from Long Island. Throughout the building proper, ¾-in. broken stone—trap rock and limestone—was used, with the exception of considerable quantities of gravel in which no pieces had a greater maximum diameter than about ¾ in. In some of the larger masses of the retaining walls and other similar parts of the foundation and basement of the building, 1½-in. broken stone was used.

The proportions of the concrete for the entire building were: one of cement, two of sand, and four of broken stone or gravel by volume. The consistency of the concrete was very nearly or quite wet enough to be that termed semi-liquid, so that it was truly "poured" into all forms for columns, walls and floors. Such a consistency of concrete is imperative for reinforced concrete construction of this class. It enables the concrete to form an intimate and dense matrix around the steel reinforcement, and produces a most excellent quality of material. While the concrete was being poured laborers with long thin sticks continually agitated the fresh concrete in order to release all air bubbles and insure a dense and continuous product and the best possible bond with the embedded steel. There was no sensible excess of water in the concrete, but it was practically semi-liquid—too thin even to quake. The results throughout the entire work, in this respect, have proved to be in the highest degree satisfactory. The total quantities of the principal materials used were:

Cement	8 500 bbl.
Sand	3 000 cu. yd.
Broken stone	4 300 cu. yd.
Gravel	1 066 cu. yd.
Steel in latticed angle columns	655 tons.
Steel in round reinforcing rods	507 tons.

SPECIFICATIONS FOR CEMENT AND CONCRETE FOR THE MCGRAW BUILDING.

Cement.—All the cement used in this structure shall be true Portland cement of the quality prescribed in the specifications of the Com-

mittee of the American Society of Civil Engineers. The tests required to establish the suitability of the cement will be in accordance with those prescribed in the American Society specifications.

Concrete.—The concrete shall be composed of cement, sand and broken stone, or gravel, mixed with clean water.

The sand may be natural sand or the finer product of the stone crusher. It shall be clean, hard, and preferably of varying sizes, so as to reduce the volume of voids. The gravel or broken stone shall be of varying sizes, free from sensible amounts of clay, loam, or foreign matter. The largest pieces shall not exceed 1½ in. in their largest dimension.

All concrete shall be thoroughly mixed so as to work the cement uniformly through the entire mass. All particles of sand, gravel, or broken stone must be completely coated with cement, and all the voids entirely filled.

All concrete shall be mixed in a machine mixer. The volume of matrix and the aggregate with the requisite quantity of water shall be kept in the mixer long enough to produce the intimate admixture desired. The quantity of water used shall be sufficient to make a wet or even semi-liquid concrete, so that it will readily run or flow into all the small spaces to be filled around all classes of steel reinforcement, whether in the floors or in the columns. This concrete shall be too wet to ram, but, while being poured and immediately thereafter, it must be actively agitated by long thin rods so as to expel all entrained air and produce a continuous and intimate bond with the steel embedded in it.

All concrete for the building proper, *i. e.*, above the foundations, shall be composed of such proportions of cement, sand, and gravel, or broken stone, as will make a perfectly solid mass, with a little surplus of cement over that required to fill the voids. The proportions of this mixture will be equivalent to 1 volume of cement, 2 volumes of sand, and 4 volumes of gravel, or broken stone.

In these provisions for the concrete it is the intention to take advantage of balanced sand, gravel, or broken stone, *i. e.*, to use varying sizes for the purpose of decreasing the voids, and using less cement to secure the best results. It will probably be necessary, therefore, to experiment with different proportions of different sizes of sand and gravel, or broken stone, in order to ascertain the best mixture of the available materials at hand to secure the desired ends.

The largest pieces of the aggregate, *i. e.*, gravel, or broken stone, for the building proper shall not exceed ¾ in. in their greatest dimension. For the retaining or area walls around the basement of the building, and in foundation masses, the maximum size of broken stone or gravel in the aggregate may be 1½ in.

The proportions of the concrete for the retaining or area walls and foundation masses shall be 1 volume of cement, 3 volumes of sand, and 5 volumes of gravel, or broken stone, the aggregate being balanced or graded so as to reduce to a minimum the voids to be filled with the cement.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

INVAR (NICKEL-STEEL) TAPES ON THE MEASUREMENT OF SIX PRIMARY BASE LINES.

By Owen B. French, M. Am. Soc. C. E.

To be Presented December 4th, 1907.

Until near the end of the last century, geodesists considered some form of bar apparatus necessary for the accurate measurement of primary base lines. The use of any bar apparatus is very expensive, hence, when it became apparent that frequent bases were required in a triangulation scheme, a more economical form of measuring apparatus was necessary. As the question of economy would undoubtedly be solved by the use of long tapes or wires, many attempts were made to devise some means of securing a satisfactory degree of accuracy with apparatus of this type. Long steel tapes or wires had been in use for many years for measuring purposes, but, until about 1890, they were not considered accurate enough for primary measurement. Although many had investigated the use of tapes for accurate measurement, to a greater or less extent, one of the first to make a successful investigation was Professor R. S. Woodward, while he was an Assistant on the United States Coast and Geodetic Survey.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

The results of his work and their discussion, together with the mathematical formula required for the general use of tapes, may be found in Appendix 8 of the Coast and Geodetic Survey Report for 1892.*

Previous Work with Steel Tapes.—The long steel tapes used by Professor Woodward in his investigations have been used since in the measurement of a number of base lines by the Coast and Geodetic Survey. The most important work of this character was the measurement of nine base lines along the 98th meridian, by Mr. A. L. Baldwin, in 1900.† A direct comparison between the measurements with bars and steel tapes was made on each of the nine bases. The duplex bar apparatus—one of the best forms of bar apparatus known—was used, and also both 50 and 100-m. steel tapes. The results of this work demonstrated that steel tapes, when used at night, and standardized under the same conditions that prevail during the base measures, gave practically the same degree of accuracy as the duplex apparatus, for about one-third of the cost. This work also demonstrated that the gain, either in accuracy or economy, by the use of a tape more than 50 m. long, was so small as to fail to offset the gain in convenience of manipulation in the field possessed by the shorter tape. Consequently, the Coast and Geodetic Survey, until recently, has considered the 50-m. steel tape the best form of base-measuring apparatus, if used at night, when the temperature of the tape can be obtained very accurately.

Invar, or Nickel-Steel Alloy.—When, a few years ago, Dr. C. E. Guillaume, Assistant Director of the International Bureau of Weights and Measures, near Paris, discovered an alloy of nickel and steel which possessed a small coefficient of expansion, its use for base measurement was immediately suggested, as the effect of temperature errors would undoubtedly be greatly reduced by using such a metal. This alloy is made near Paris by a secret process, and contains about 36% of nickel. It has been given the name of "invar," a word derived from the same root as the word invariable, and having a similar meaning.

Guillaume's investigations of the properties of this alloy have been quite extensive. The results of his work have been published from time to time in such scientific publications as *Bulletins des Séances de la Société Française de Physique, Archives des Sciences, Comptes*

* "On the Measurement of the Holton Base, Holton, Ripley County, Indiana, and the St. Albans Base, Kanawha County, West Virginia."

† "On the Measurement of Nine Bases Along the Ninety-eighth Meridian," Apx. 3, U. S. Coast and Geodetic Survey Report, 1901, p. 229.

Rendus, Journal de Physique, Metallographist, etc., in addition to the publications of the International Bureau of Weights and Measures.

Guillaume's investigations extend over a period of several years, and, in so far as they apply to base measurement, have been made with bars, or wires, usually 24 m. long.

U. S. Coast and Geodetic Survey Invar Tapes.—The use of wires instead of tapes has not been considered advisable on the Coast and Geodetic Survey, the objections to wires being considered of more consequence than the objections to tapes.

As soon as Guillaume's investigations with the invar wires had advanced far enough to prove that the metal is comparatively stable, the Coast and Geodetic Survey decided to test some tapes of this alloy. Although invar wires could be obtained with little difficulty, no invar tapes could be secured until December, 1905, when they were purchased in London, England.

These invar tapes are about 52 m. (171 ft.) long, 6.3 mm. (0.25 in.) wide, and 0.5 mm. (0.02 in.) thick, with a mass of about 25 g. per m. of length (0.027 oz. per ft. of length). They are slightly longer and heavier than the steel tapes used by the U. S. Coast and Geodetic Survey, the mass of the latter being about 20 g. per m. of length.

The invar tapes are considerably brighter than the steel tapes, being more nearly like nickel in appearance. Although they are less easily oxidized than steel tapes, they require almost as much care in order to keep them free from rust. The metal is softer, more easily bent, and less elastic than steel.

When these tapes were laid, without tension, upon a flat surface, they appeared crooked, being full of small bends in all directions. These bends were not large enough, however, to cause any part of the tape to be more than about ½ in. from a straight line. The large bends were removed from all tapes used for base measurement, before beginning the standardization.

When the tapes were stretched under a tension of 15 kg. (the tension used on all the measures), the remaining small bends were practically eliminated, although in certain lights numerous minute irregularities were distinctly visible. These small irregularities were so nearly the same every time the tape was stretched under a tension of 15 kg., that the length of the tape was practically constant. This was proven in the standardization of these tapes.

The measurement of several primary base lines had been postponed a year or more by the Coast and Geodetic Survey, in hope of securing some of these invar tapes; hence, when they were received, preparations for the measurement of these bases were immediately begun.

Several of the invar tapes were prepared for measuring purposes, in the same manner as the steel tapes, by the Instrument Division of the Coast and Geodetic Survey. Small silver sleeves were riveted rigidly to each tape near either end, to carry the graduation marks, the distance between the two marks on a tape being very nearly 50 m.

An aluminum reel, 16 in. in diameter, was made for each tape. The size of these reels was not considered of sufficient consequence to warrant special investigation, hence it was fixed in accordance with a statement made by Mr. Baugh when transmitting the tapes.

The fact that these reels are not small enough to affect the length of a tape was proved during the standardization by reeling and unreeling one tape one hundred times on several different days, no change in its length being noticeable.

Investigations of the Properties of Invar Tapes.—Notwithstanding the fact that Guillaume's investigations with invar wires were quite extensive and satisfactory, it was considered best to make experiments enough with these tapes to be certain that they did not possess properties which would affect materially the accuracy of any measures that might be made with them. Consequently, several short pieces of the tapes were tested, at the National Bureau of Standards, in order to find:

First.—The tensile strength;

Second.—The yield point; and

Third.—Whether the continued application and removal of small loads affected the length of the tape.

The tensile strength was found to be about 100 000 lb. per sq. in. (practically one-half that of ordinary tapes), a load of more than 450 lb. being required to break the specimens. The yield point, determined with a Henning mirror extensometer, was about 70% of the tensile strength.

One specimen had a load of 40 lb. suspended from it for 60 hours, without showing any change in length. Loads up to 60 lb. were applied and removed on one of the specimens many times, the lengths corresponding to the same loads being practically identical.

The results of these experiments were very satisfactory; and no properties derogatory to the use of these tapes for measuring purposes were discovered.

Disadvantages of Steel Tapes.—Steel tapes must be standardized in the field and used at night in order to obtain the accuracy required for the measurement of primary base lines. The cost of the measurement is increased very considerably on this account. As these conditions are necessary, owing to the uncertainty in the determination of the temperature of the tape, it was hoped that this expense could be eliminated by using a metal which possessed a small coefficient of expansion. Consequently, the invar tapes were standardized at the Bureau of Standards both before and after the field measures.

Night measures are objectionable for many reasons: The necessity for illumination causes a loss in accuracy and also a loss in speed, thus increasing the cost of the work. Therefore, the invar tapes were used during daylight hours only.

Owing to the fact that the invar tapes were unknown, and that there was a possibility of their proving too unstable for accurate work, it was decided to make a complete measurement of all the bases with the steel tapes as well as with the invar tapes, thus insuring a satisfactory determination of the lengths of the bases and affording a means of studying the relative action of the two kinds of tapes.

Standardization.—The steel tapes were used entirely at night and standardized in the field just before and just after the measurement of the six bases. The invar tapes were standardized at the Bureau of Standards.

All the tapes were standardized in practically the same manner, by comparing them many times with a 50-m. comparator, the length of which was obtained with the iced-bar apparatus.

The 50-m. comparator used at the Bureau of Standards is located in a tunnel about 2½ m. high and wide, and 52 m. long. Along one wall of this tunnel are a number of pipes through which brine, at a temperature of —10°, may be pumped to get low temperatures. The iced bar used for this work is the one designed by Professor Woodward, and described in the Coast and Geodetic Survey Report for 1892. It is a steel bar, a little more than 5 m. long, the measure being the distance between two fine lines cut into platinum iridium plugs, one near each end of the bar. The bar is supported by adjustable bolts

in a V-trough, the trough resting upon trucks also adjustable. A track was built in the floor of the tunnel for these trucks to run upon so that the bar could be moved along rapidly. Microscopes for holding the measure while the bar was being run ahead were mounted upon heavy iron arms, one end of each being attached, in an adjustable manner, to the top of a stone post. These posts were 5 m. apart, the length of the bar. A hole was cut through the top of each post to permit the light from an electric bulb, suspended back of the post, to supply the illumination for the microscope. Each stone post was mounted upon a concrete pier.

The microscopes were carefully aligned by a fine wire stretched between the end microscopes and near the foci of all. The heights of the microscopes were such that their foci were nearly in a straight line which was practically horizontal.

The inclination of the bar in each position (the end marks of the bar being in the foci of the microscopes) was determined with a sector attached to the side of the trough, thus giving data for the elimination of the effect of the small differences in height between the foci of the microscopes.

The ends of the comparator were marked by spherical-headed bolts set in the concrete piers which support the end microscope posts. These marks were directly under the end microscopes which were referred to the end marks frequently during the standardization by the cut-off cylinders used heretofore.

The bar was aligned and leveled in the usual manner, the trough being kept as full of crushed ice as possible during each operation. The bar was usually surrounded with ice at least a half hour before beginning the measurement.

A determination of the length of the comparator consisted of at least two measures with the iced bar in opposite directions.

When making the tape comparisons at the Bureau of Standards, a determination of the length of the comparator was made at the beginning and also at the end of each day's work. When at work in the field such a determination was made before beginning the tape comparisons, after their completion, and at intermediate times, if necessary to make the interval between the tape comparisons and comparator determination less than 24 hours.

The lengths of the tapes were obtained by stretching them under

the end microscopes of the comparator, always supporting and handling them in practically the same manner as they were to be used in the field. The invar and steel tapes were handled in exactly the same manner. The tape was supported at the graduation marks and also at one point in the middle in line with the end supports. A tension of 15 kg. was used, indicated by a spring balance having a dial with a hand working over its face. A complete revolution corresponded to 5 kg. The tension could be read to about 10 g. without difficulty.

A thermometer with a metal back was fastened 1 m. from the graduation mark (and toward the middle), at each end of the tape. These were always read immediately after making pointings upon the graduation marks of a tape.

During standardization the rear end of the tape was held rigidly by an adjustable clamp. The forward or balance end was held by an adjustable ratchet device, at the Bureau of Standards, and by the tape stretcher used on the base measurement, for the field standardization.

A determination of the length of the tape consisted of two simultaneous pointings by the two observers on the graduation marks of the tape, followed immediately by two more after the observers had exchanged places.

An ordinary day's work was found to be a double comparison of from six to eight tapes, with an iced-bar determination of the length of the comparator, both before and after. During February, 1906, before beginning the base measures, twelve or thirteen comparisons were obtained for each of the six invar tapes, six comparisons at a temperature of about $+4°$ cent., and the remainder at about $+25°$ cent. After the base measures, in October, 1906, five of these tapes were again standardized, four comparisons being obtained for each.

The results of the standardization for the five invar tapes are as follows, each temperature being the mean of all the observed temperatures for that tape, as the length is the mean of all the observed lengths:

	Temperature, in degrees, cent.	Length, in millimeters.	
Tape No. 437.			
February, 1906.....	14.24	+7.816	
October, 1906.....	25.62	+8.079	
Mean.....	19.93	7.947	±0.007 mm.

	Temperature, in degrees, cent.	Length, in millimeters.	
Tape No. 438.			
February, 1906.....	14.26	+ 8.057	
October, 1906.....	25.60	+ 8.380	
Mean.....	19.93	+ 8.218	± 0.009 mm.
Tape No. 439.			
February, 1906.....	14.24	+ 6.578	
October, 1906.....	25.60	+ 6.864	
Mean.....	19.92	+ 6.721	± 0.007 mm.
Tape No. 440.			
February, 1906.....	14.38	+ 9.418	
October, 1906.....	25.70	+ 9.702	
Mean.....	20.04	+ 9.560	± 0.008 mm.
Tape No. 442.			
February, 1906.....	14.16	+ 9.218	
October, 1906.....	25.45	+ 9.548	
Mean.....	19.80	+ 9.383	± 0.010 mm.

Table 1 shows the individual values for Tape No. 440, and is a fair sample of the manner in which the results agree:

TABLE 1.—INDIVIDUAL VALUES OF INVAR TAPE NO. 440.

Date.	Temperature in degrees, cent.	Observed length 50 m., in millimeters.	Computed length 50 m., in millimeters.	Computed minus observed length, in millimeters.
1906.				
Feb. 10.....	27.3	+ 9 666	+ 9.696	+ 0.030
" 12.....	4.4	9.208	9.268	+ 0.060
" 12.....	4.3	9.199	9.266	+ 0.067
" 13.....	3.9	9.195	9.258	+ 0.063
" 13.....	4.1	9.186	9.262	+ 0.076
" 15.....	3.3	9.225	9.247	+ 0.022
" 15.....	2.2	9.287	9.227	− 0.060
" 17.....	24.5	9.587	9.643	+ 0.056
" 17.....	24.6	9.615	9.645	+ 0.030
" 19.....	25.7	9.650	9.666	+ 0.016
" 19.....	24.6	9.616	9.645	+ 0.029
Mar. 1.....	24.1	9.600	9.636	+ 0.036
" 1.....	24.6	9.596	9.645	+ 0.049
Mean.....	14.38	+ 9.418	.....	.....
Oct. 4.....	25.7	+ 9.716	9.666	− 0.050
" 4.....	25.8	9.686	9.668	− 0.018
" 5.....	25.4	9.685	9.660	− 0.025
" 5.....	25.9	+ 9.721	9.670	− 0.051
Mean.....	25.70	+ 9.702		
Final Mean.....	20.04	+ 9.560 ± 0.008		

The quantities in the column headed "Computed" were obtained from the final mean by reducing it to the temperature of the individual values. The probable error was computed from the residuals given in the last column.

By reducing all the values obtained in the February standardization to the temperature of the October standardization, it was found that there was a slight lengthening of all the tapes during this period. However, as there are residuals of both signs in the February work, at least a part of this difference may be apparent rather than actual. It averages about 1 part in 800 000 for the five tapes, the greatest being 1 part in 617 000. If this change took place uniformly, the mean of the two standardizations gives values from which the lengths of the bases are obtained very accurately. Even if it were a sudden change, the error on any base from this source could not be more than 1 part in 1 600 000, and might be much less. It was probably a more or less gradual change, as there was nothing in the measures to indicate any sudden change. It may have been due to a change in the molecules of the tape itself, but is more likely to have been a straightening out of the many small bends in the tapes. If the latter, it may have been either a gradual change or a sudden one, although the former is the more probable.

Tapes Nos. 437 and 442 were never used, except for the comparisons. Tape No. 437 was taken into the field, but was not used on the base measures. Tape No. 442 was not even taken into the field. The large bends were not removed from Tape No. 442 before standardizing it, and the graduation marks were very irregular, hence its change is probably due partly to these two conditions. As the largest change was only 0.08 mm. per tape length, a quantity barely perceptible to the naked eye, it is certainly not of serious consequence in any case. Steel tapes have been found to change length more than this.

Coefficients of Expansion.—The coefficients of expansion for these tapes were computed from the February observations, the large range in temperatures having been secured for this purpose. During this work at the Bureau of Standards, four steel tapes were also compared for the purpose of getting their coefficients of expansion. Table 2 shows the results obtained for all the tapes:

These coefficients for the invar tapes are very small, being practically one-twenty-eighth of steel tapes. They are about one-half those

of the wires used in the base measurement through the Simplon Tunnel, by Guillaume, thus showing that they are probably smaller than those usually obtained for this alloy.

TABLE 2.

Tape Number.	Expansion per degree centigrade per 50 m.	Probable Error.	Coefficient per unit length per degree centigrade.
Invar No. 437	0.0207	±0.0009	0.000 000 41
" " 438	0.0213	0.0008	0.000 000 43
" " 439	0.0203	0.0006	0.000 000 41
" " 440	0.0187	0.0006	0.000 000 37
" " 442	0.0220	0.0009	0.000 000 44
Steel No. 403	0.568	±0.003	0.000 011 4
" " 404	0.568	0.003	0.000 011 4
" " 405	0.569	0.004	0.000 011 4
" " 406	0.565	0.003	0.000 011 3

Bases Measured.—Early in March, 1906, the party left Washington, D. C., to measure six base lines. The first measured was Point Isabel Base, in Southern Texas, near the mouth of the Rio Grande River; second, Willamette Base, in the Willamette Valley, Oregon; third, Tacoma Base, near Tacoma, Wash.; fourth, Stephen Base, near Stephen, Minn.; fifth, Brown Valley Base, South Dakota, near Brown Valley, Minn.; and, last, Royalton Base, near Royalton, Minn. The first, fourth and fifth bases control part of the triangulation along the 98th meridian; the two on the Pacific Coast control the main scheme along that coast between the 39th-parallel triangulation and the Puget Sound work. The last base controls, in part, the triangulation which connects the 98th-meridian scheme with the triangulation of the Great Lakes near Duluth.

All six bases were measured with three steel tapes and also with three invar tapes, each tape being used on about two-thirds of each base. Two complete measures of each base were made with the steel tapes and two with the invar, the steel tapes being used at night only and the invar in the daylight. The measures were arranged so that a complete inter-comparison of all the tapes was obtained on each base.

Field Standardization.—The steel tapes were standardized at the first and also at the last base measured. A 50-m. comparator was built at each of these places, and its length was determined with the iced bar in the same manner as at the Bureau of Standards. The method

of making the tape comparisons was the same as that used at the Bureau of Standards, except that the regular tape stretcher used in the base measures was used at the forward end on the field standardization. Two comparisons were obtained for each of the steel tapes, on each of two nights, at both standardizations, or eight comparisons in all for each tape.

Adopted Lengths of All Tapes.—The adopted lengths and other data for the steel tapes, as derived from the field comparisons, are given in Table 3. The coefficient of expansion was obtained from the work at the Bureau of Standards. The table also gives the adopted lengths and other data for the invar tapes as obtained from the observations at the Bureau of Standards, which have been previously described.

TABLE 3.

STEEL TAPES.

	mm.	mm.	Degrees.
$T_{248} = 50$ m. +	3.51	+ 0.527	$(t - 20.62)$
	± 0.010	± 0.003	
$T_{403} = 50$ m. +	12.12	+ 0.568	$(t - 20.59)$
	± 0.024	± 0.003	
$T_{405} = 50$ m. +	12.56	+ 0.569	$(t - 20.74)$
	± 0.017	± 0.004	
$T_{406} = 50$ m. +	12.34	+ 0.565	$(t - 20.88)$
	± 0.021	± 0.003	

INVAR TAPES.

	mm.	mm.	Degrees.
$T_{437} = 50$ m. +	7.947	+ 0.0207	$(t - 19.93)$
	± 0.007	± 0.0009	
$T_{438} = 50$ m. +	8.218	+ 0.0213	$(t - 19.93)$
	± 0.009	± 0.0008	
$T_{439} = 50$ m. +	6.721	+ 0.0203	$(t - 19.92)$
	± 0.007	± 0.0006	
$T_{440} = 50$ m. +	9.560	+ 0.0187	$(t - 20.04)$
	± 0.008	± 0.0006	
$T_{442} = 50$ m. +	9.383	+ 0.0220	$(t - 19.80)$
	± 0.010	± 0.0009	

Field Procedure.—The preparation of the base lines for measurement was practically the same as for previous base measurements with steel tapes. Posts, 4 by 4 in., were driven every 50 m. along the line, with posts 2 by 4 in. midway between them. A nail, for the middle support of the tape, was driven into each of the 2 by 4-in. posts, in line

with the tops of the adjoining 4 by 4-in. posts, or raised enough so that the tape would clear the ground or other objects. In this case its height was determined while running the levels over the base. All these posts were carefully aligned with a theodolite. Forward sights only were used, and posts were rarely set on more than 300 m. from one position of the instrument. There was probably no tape length that was out of parallelism to the base by as much as 1 cm., thus eliminating errors from this source.

A forward and backward line of levels was run over each base to determine the height of each 4 by 4-in. post and all 2 by 4-in. posts which were not on grade with the tops of adjoining 4 by 4-in. posts. The difference in height of any two adjoining posts was probably obtained within 1 cm., hence errors from this source are also negligible. The corrections for grade were obtained from a table prepared for the argument, difference in height, h, using the formula:

$$c = -\frac{h^2}{2s} - \frac{h^4}{8s^3} - \frac{h^6}{16s^5} -, \text{ etc.},$$

s in this case being 50 m.

Copper strips, of the same thickness as the graduation sleeves on the tapes, were nailed to the tops of the 4 by 4-in. posts to hold the marks for the measures. Each base was divided into sections about 1 km. in length. The various measures of a section were all referred to the same lines on the copper strips of the terminal posts, hence are directly comparable.

Heavier posts were set very solidly at the ends of the sections to hold the measure for several days, if necessary. Only complete sections were measured at one time, thus the 4 by 4-in. posts were not depended upon to hold the measure for more than a few minutes.

The tapes were stretched over the 4 by 4-in. posts, with a thermometer attached to the top, in the same manner as in the standardization. The rear end was held by a small steel bar. The forward end was attached to the hook of the balance, which was fastened to the stretcher by a gimbal attachment with counterpoise, so that the balance could always be kept horizontal. A steel point was fastened at the lower end of the stretcher bar, and a quick and accurate adjustment for the height of the tape was made without using the screw adjustment, by merely pressing the stretcher into the ground more or less as might be required.

All 4 by 4-in. posts were set at a uniform height above the ground (about ½ m.), so that no time would be lost during the measure in adjusting the tape stretcher.

Party Organization.—The measuring party was composed of two observers, two tape stretchers, one recorder, and two men to support the middle of the tape while it was being carried forward, seven in all. The first three bases were prepared by the measuring party, but the last three were prepared by a separate party, consisting of five men. This party prepared three bases, aggregating a length of 27 km., in 17 working days. This time includes delays on account of weather and travel between bases. The latter required four days. On about a kilometer of one base, the posts were set in a pond where the water was about 2 ft. deep, and each post in the water was double braced in order to insure its stability, thus delaying the preparations very materially. This party had no difficulty in preparing between 3 and 4 km. per day, under ordinary conditions. When the preparation party finished with a base, everything was ready for beginning the measures. The copper marking strips were usually nailed to the tops of the posts during the first measure.

Speed of Measurement.—A single measurement of 12 km. was found to be an ordinary day's work, when half of it was made at night. Occasionally, 14 km., or more, were measured in one day. This, however, occurred only when the work had been delayed from some cause, and was too much to be maintained for any length of time. The speed with which the measurement progressed was a trifle more rapid with the invar than with the steel tapes. After the party acquired some experience, a speed of more than 2 km. per hour was ordinarily maintained. The average speed for the invar measures on the last base was 2.6 km. per hour, the whole party being well trained by this time. No attempt was made merely to acquire speed, a tape length never being marked until everything was apparently steady and correct.

Record and Computation.—The record kept on this work was very simple. It consisted principally of two thermometer readings for each tape length, with an occasional set-up or set-back, made in order to keep the marks on the copper marking strips. Notes as to the condition of the weather, or the occurrence of anything that might affect the measures, were inserted whenever needed. In making the computations the average temperature for each section was used to deter-

mine the average length of the tape during the measurement of that section.

Table 4 gives the results of the measures for each section of the Brown Valley Base, and is a fair sample of the form of computation and differences between the results for the individual sections, as obtained on all the bases.

In Table 4 the time is given in hours and tenths. All measures with steel tapes were made at night, and all measures with invar tapes in the daytime, hence it is unnecessary to insert A. M. or P. M. The columns headed "Weather," "Wind," "Temperature," "Temperature, rising or falling," and "Temperature range" are inserted to permit the study of possible sources of errors. The abbreviations used in these columns are: R = rising; F = falling, for temperature; F = fair; C = cloudy; P = Partly cloudy; R = rain; M = mist; and D = dew, for weather conditions; L = light; M = moderate; and H = fresh, for wind, with the usual abbreviations for its direction. The temperature range is given to tenths of degrees for the steel tapes, but only to degrees for the invar tapes, owing to their smaller coefficients of expansion.

Column 6 shows the average temperatures for each measurement of a section, corrected for thermometer errors. Column 11 gives the corrections to the tapes due to differences between this temperature of observation and that of standardization for the particular tape. Column 12 gives the grade corrections as obtained from the difference in heights between adjoining posts, as previously mentioned in this paper. Column 13 gives the reduction to sea level obtained from the average height of the section, h, using the formula

$$c = -s\frac{h}{\rho} + s\frac{h^2}{\rho^2} - s\frac{h^3}{\rho^3} +, \text{ etc.},$$

s being the length of the section, and ρ the radius of curvature of the earth for this base line. Column 14 gives the algebraic sums of the set-ups and set-backs for each measure of the sections. Column 15 gives the tape corrections for the sections, obtained by multiplying the excess of the length of the tape over 50 m. by the number of tape lengths in the section. Column 16 shows the algebraic sum of Columns 11 to 15. These quantities are the results of the individual measures for the various sections. Column 17 shows the lengths of the sections as determined with the steel tapes, and Column 18, the lengths as

determined with the invar tapes. Column 19 gives the residuals for the various measures of the sections, not combining the invar and steel results. Column 20 shows the differences between the invar and steel measures of the various sections.

Computation of Probable Errors.—The probable error for the base was determined as follows: The probable error of each section was determined from the residuals of Column 19, keeping the measures with the steel and invar tapes separate. These values were combined with the probable errors of the tapes, the latter being obtained by multiplying the probable error of one length of the tape, given with the adopted lengths of tapes, by the number of tape lengths in the section.

The probable error of the length of the base, given by the steel tapes, was obtained by taking the square root of the sum of the squares of the probable errors of all the sections obtained from the measures with steel tapes, and the probable error of the length from the measures with the invar tapes, by a similar combination of the probable errors of the sections obtained from measures with invar tapes.

Probable error of measures with steel tapes, Brown Valley
Base ..... ± 4.98 mm.
Probable error of measures with invar tapes, Brown Valley
Base ..... ± 2.05 mm.

These values were then combined with the probable errors due to the probable errors of the coefficients of expansion. The latter were obtained by taking the sum of all the temperature differences between the observed and standard temperatures of the tapes on the base and multiplying this by the average probable error of the coefficients of expansion of the tapes, these probable errors being nearly equal.

The probable error due to probable errors of coefficients of expansion for steel tapes was..... ± 2.46 mm.

The probable error due to probable errors of coefficients of expansion for invar tapes was..... ± 0.22 mm.

Combining these with the values already given we have:
Probable error due to measurements and coefficients:

Steel tapes ..... ± 5.55 mm.
Invar tapes ..... ± 2.06 mm.
Weighted mean, steel and invar tapes..... ± 2.09 mm.

TABLE 4.—RESULTS OF MEASURES

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Number of section and posts.	Date.	Time of day.	Direction of measure.	Number of tape.	Mean Temperature.	Temperature, Range.	Temperature, Rising or Falling.	Weather.	Wind.	Temperature.
	1906.	Hour.			Degrees.	Degrees.				
1	June 27	9.7	SE.	440	24.33	6	RF	P	LS	+0.0016
S. E. B. to 20...	June 27	10.2	NW.	438	25.28	5	RF	P	LS	+0.0023
	June 27	9.0	SE.	406	21.05	0.6	RF	PD	.....	+0.0019
	June 27	9.5	NW.	403	21.20	0.9	F	PD	.....	+0.0069
2	June 27	9.1	SE.	440	22.77	6	R	P	LS	+0.0010
20 to 40.....	June 27	10.7	NW.	438	26.40	6	RF	P	LS	+0.0028
	June 27	8.5	SE.	406	20.39	1.4	FR	PD	.....	−0.0055
	June 27	10.0	NW.	403	20.10	1.0	F	PD	.....	−0.0056
3	June 26, 27	.....	SE.	440	21.15	3	RF	P	LN	+0.0004
40 to 60.....	June 27	11.0	NW.	438	24.60	3	F	P	LN	+0.0013
	June 27	3.2	NW.	439	24.46	3	RF	P	LN	+0.0006
	June 29, 27	.....	SE.	406	19.68	2.0	F	PD	.....	−0.0136
	June 29	10.5	NW.	403	19.57	0.6	FR	PD	.....	−0.0076
	June 29	9.0	NW.	405	15.98	0.6	RF	PD	.....	−0.0190
4	June 26	4.0	SE.	440	22.90	5	FR	P	LN	+0.0011
60 to 80.....	June 26	3.6	NW.	439	25.02	5	RF	P	LN	+0.0021
	June 29	9.9	SE.	406	14.72	3.0	RF	DF	LE	−0.0696
	June 29	9.5	NW.	405	13.69	4.1	F	FD	LE	−0.0802
5	June 26	4.4	NW.	439	25.50	5	RF	P	LN	+0.0023
80 to 100.....	June 26	5.2	SE.	440	24.82	3	RFR	P	LN	+0.0018
	June 29	10.0	NW.	405	12.53	1.7	FR	FD	LE	−0.0934
	June 29	11.0	SE.	406	13.16	1.8	FR	FD	LE	−0.0872
6	June 26	4.6	NW.	439	24.45	3	R	P	LN	+0.0005
100 to 105.....	June 26	5.0	SE.	440	25.46	2	F	P	LN	+0.0005
	June 29	10.3	NW.	405	12.02	0.4	R	FD	LE	−0.0222
	June 29	10.5	SE.	406	12.76	0.5	R	FD	LE	−0.0207
7	June 26	9.0	NW.	438	18.28	3	FR	P	L	−0.0007
105 to 125.....	June 26	11.4	SE.	439	20.71	6	RF	P	L	+0.0003
	June 30	8 5	NW.	405	11.20	1.4	FR	FD	LNE	−0 1086
	June 30	10.8	SE.	403	8.83	1.5	FR	FD	LNE	−0.1336
8	June 26	9.5	NW.	438	19.66	6	RF	P	L	−0.0001
25 to 145.....	June 26	10.9	SE.	439	22.32	7	F	P	L	+0.0010
	June 30	8.9	NW.	405	10.47	1.3	FR	FD	LNE	−0.1169
	June 30	10.4	SE.	403	9.52	1.3	FR	FD	LNE	−0.1258
9	June 26	9.9	NW.	438	20.96	5	RF	P	L	+0.0004
145 to N. W. B...	June 26	10.5	SE.	439	22.34	6	FR	P	L	+0.0010
	June 30	9.4	NW.	405	9.56	0.9	FR	FD	LNE	−0.1272
	June 30	9.9	SE.	403	9.64	1.0	FR	FD	LNE	−0.1244

* This section was measured in part with each of the tapes given.
† Full or half-tape lengths did not fit between the ends of this section, hence, the fractional

OF BROWN VALLEY BASE.

Corrections.				(16)	(17)	(18)	(19)	(20)
(12)	(13)	(14)	(15)					
Grade.	Sea Level.	Set-up or Set-back.	Tape Length.	Corrected length of section.	Mean Length, Steel tapes.	Mean Length, Invar tapes.	Residual, Mean: Observed.	Difference, Invar: Steel.
				mm.	mm.	mm.		
−0.0805	−0.0542	+0.0389	+0.1912	1 000.0970	.....	.....	−0.5	.....
.....	.....	+0.0644	+0.1644	.0964	.....	1 000.0967	+0.3	.....
.....	.....	−0.0113	+0.2468	.1027	.....	.....	−1.5	.....
.....	.....	−0.0148	+0.2424	.0998	1 000.1012	.....	+1.4	−4.5
−0.0143	−0.0538	−0.0843	+0.1912	1 000.0398	.....	1 000.0397	−0.1	.....
.....	.....	−0.0595	+0.1644	.0396	.....	.....	+0.1	.....
.....	.....	−0.1335	+0.2468	.0397	.....	.....	+0.3	.....
.....	.....	−0.1285	+0.2424	.0402	1 000.0400	.....	−0.2	−0.3
−0.0130	−0.0541	−0.1290	+0.1912	999.9955	.....	.....	0.0	.....
.....	.....	−0.0932 *	+0.1069 *	.9955	.....	999.9955	0.0	.....
.....	.....		+0.0470 *	.....	.....	.....	.....	.....
.....	.....	−0.1679	+0.2468	.9982	.....	.....	−1.1	.....
.....	.....	−0.1559 *	+0.1576 *	.9959	.....	.....	+1.2	.....
.....	.....		+0.0879 *	.....	999.9971	.....	.....	−1.6
−0.0126	−0.0541	−0.0292	+0.1912	1 000.0964	.....	.....	+0.9	.....
.....	.....	+0.0284	+0.1344	.0982	.....	1 000.0973	−0.9	.....
.....	.....	−0.0166	+0.2468	.0939	.....	.....	−0.3	.....
.....	.....	−0.0110	+0.2512	.0933	1 000.0936	.....	+0.3	+3.7
−0.0104	−0.0543	+0.0215	+0.1344	1 000.0931	.....	.....	−1.0	.....
.....	.....	−0.0369	+0.1912	.0910	.....	1 000.0921	+1.1	.....
.....	.....	−0.0026	+0.2512	.0901	.....	.....	+0.5	.....
.....	.....	−0.0034	+0.2468	.0911	1 000.0906	.....	−0.5	+1.5
−0.0061	−0.0122	+0.0066	+0.0303	222.9643†	.....	.....	+0.2	.....
.....	.....	−0.0057	+0.0430	.9647	.....	222.9645†	−0.2	.....
.....	.....	+0.0024	+0.0565	.9636†	.....	.....	0.0	.....
.....	.....	+0.0018	+0.0556	.9636	222.9633†	.....	0.0	+0.9
−0.0298	−0.0544	+0.0297	+0.1644	1 000.1092	.....	.....	+1.8	.....
.....	.....	+0.0623	+0.1344	.1128	.....	1 000.1110	−1.8	.....
.....	.....	+0.0464	+0.2512	.1048	.....	.....	+2.9	.....
.....	.....	+0.0860	+0.2424	.1106	1 000.1077	.....	−2.9	+3.3
−0.0419	−0.0547	+0.0359	+0.1644	1 000.1036	.....	.....	+1.9	.....
.....	.....	+0.0686	+0.1344	.1074	.....	1 000.1055	−1.9	.....
.....	.....	+0.0633	+0.2512	.1010	.....	.....	+3 3	.....
.....	.....	+0.08 6	+0.2424	.1076	1 000.1043	.....	−3.3	+1.2
−0.0642	−0.0553	+0.0222	+0.1644	1 000.0675	.....	.....	−0.2	.....
.....	.....	+0.0512	+0.1344	.0671	.....	1 000.0673	+0.2	.....
.....	.....	+0.0614	+0.2512	.0659	.....	.....	+5.4	.....
.....	.....	+0.0783	+0.2424	.0768	1 000.0713	.....	−5.5	−4.0

tape length (−2.0548), measured with a 3-m. bar, has been included in these lengths.

The probable errors given so far do not include the probable error in the determination of the length of the comparator. This was practically ± 0.014 mm. As the values for the tapes depend upon two standardizations, we can take $\frac{1}{2}\sqrt{2\,(0.014)^2} = \pm\ 0.010$ mm. as the probable error per tape length, resulting from the uncertainty in the length of the comparator.

As there were 164 tape lengths in the Brown Valley Base, the effect of the probable error of the comparator is $164 \times \pm\ 0.010 = \pm\ 1.64$ mm. This, combined with the last value obtained, gives the final probable error of the Brown Valley Base, ± 2.83 mm. or 1 part in 2 910 000.

This includes all known sources of error throughout all the operations necessary to obtain the length of the base in terms of the international meter.

Length of Bases.—The final lengths of the six base lines, together with their logarithms and probable errors, all computed in the same manner as described above, are given in Table 5.

TABLE 5.

Base.	Length.		Probable error.
	Meters.	Logarithm.	
Point Isabel.....	7 384.9220	3.8683459 ± 2	± 3.02 mm., or 1 part in 2 450 000
Willamette.....	14 019.3781	4.1467287 ± 1	4.09 " " 1 " " 3 430 000
Tacoma.....	12 055.5701	4.0811877 ± 2	3.99 " " 1 " " 3 020 000
Stephen.....	9 221.8333	3.9648173 ± 2	4.25 " " 1 " " 2 170 000
Brown Valley.....	8 223.5695	3.9150604 ± 1	2.83 " " 1 " " 2 910 000
Royalton.....	9 637.5508	3.9839667 ±	3.24 " " 1 " " 2 980 000
Average.....	10 090		1 part in 2 760 000
Total.....	60 543		

Comparison Between Results for Steel and Invar Tapes.—In order to afford a ready means for comparing the results obtained with the invar and steel tapes, Tables 6 and 7 are given. They show the probable errors of the measures with steel and invar tapes, computed independently.

The results shown in Tables 6 and 7 indicate that the measures with invar tapes are considerably better than those with steel tapes.

If we compare the probable errors obtained before combining with the probable errors due to comparator (as the latter are the same with both kinds of tape), it will be seen that the probable errors from the invar tapes are less than half of those from the steel, if we except the Royalton Base, where the measures with the steel tapes were exceptionally accordant. These probable errors for the measures with steel tapes agree reasonably well with those obtained heretofore, thus showing that a comparison between the measures with invar and steel tapes on these six bases is equivalent to a general comparison between the two metals.

TABLE 6.—PROBABLE ERRORS FOR MEASURES WITH INVAR TAPES.

Base.	Partial.	Due to comparator.	Combined.
	mm.	mm.	mm.
Point Isabel	± 2.83	± 1.48	± 3.19 or 1 part in 2 310 000
Willamette	± 3.13	± 2.80	± 4.20 " 1 " " 3 340 000
Tacoma	± 3.25	± 2.41	± 4.05 " 1 " " 2 980 000
Stephen	± 4.12	± 1.84	± 4.51 " 1 " " 2 040 000
Brown Valley	± 2.06	± 1.64	± 2.64 " 1 " " 3 110 000
Royalton	± 3.40	± 1.93	± 3.91 " 1 " " 2 460 000
			Mean, 1 part in 2 630 000

TABLE 7.—PROBABLE ERRORS FOR MEASURES WITH STEEL TAPES.

Base.	Partial.	Due to comparator.	Combined.
	mm.	mm.	mm.
Point Isabel	± 5.49	± 1.48	± 5.68 or 1 part in 1 300 000
Willamette	± 7.59	± 2.80	± 8.09 " 1 " " 1 730 000
Tacoma	± 6.98	± 2.41	± 7.39 " 1 " " 1 630 000
Stephen	± 7.99	± 1.84	± 8.20 " 1 " " 1 120 000
Brown Valley	± 5.55	± 1.64	± 5.79 " 1 " " 1 420 000
Royalton	± 3.80	± 1.93	± 4.27 " 1 " " 2 260 000
			Mean, 1 part in 1 500 000

According to these probable errors, the measures with the invar tapes should have a weight of 4 to 1 for measures with steel tapes in combining them for the final length of a base, if only accidental errors are considered; but as there are probably small systematic errors affecting both kinds of tapes, a weight of only 2 to 1 was used in the combination for the final length of a base.

Table 8 shows the actual discrepancy between the lengths of the

six bases as determined with invar and steel tapes, and also the proportional part each discrepancy is of the whole base.

TABLE 8.

Base.	Invar minus steel.	Proportional discrepancy.
	mm.	
Point Isabel	+ 16.5	Or 1 part in 448 000
Willamette	+ 22.0	" " " " 637 000
Tacoma	+ 40.8	" " " " 295 000
Stephen	− 19.3	" " " " 478 000
Brown Valley	+ 00.2	" " " " 41 000 000
Royalton	+ 19.9	" " " " 484 000
Average		1 part in 527 000

These differences are large when compared with the probable errors of the bases, but when compared with other instances where two forms of apparatus have been used on the measurement of a base they are very gratifying. A discrepancy of 1 in 100 000 or more between the lengths of a base obtained with two forms of apparatus is the rule rather than the exception. On the measures of 1900, the duplex apparatus gave results differing from those of the tapes by 1 in 175 000, on an average, which is three times the average discrepancy between the measures with the invar and steel tapes, and nearly twice the greatest difference.

The fact that the sign of the discrepancy between the measures with the invar and steel tapes is the same on all the bases, except one, seems to indicate a constant difference between the two sets of tapes. This one exception is probably due to the fact that part of the measures with steel tapes were made in the rain, thus causing a result sufficiently abnormal to warrant its rejection from this consideration. If the average discrepancy be considered due to errors of temperature, it would require a constant error of 5° on the measures with invar tapes, or 0.17° on the measures with steel tapes, to account for it. The temperature for the invar tapes may be in error a degree, or even a little more, but they are certainly not in error to the extent of 5 degrees. An error of 0.1°, or more, in determining the temperature of the steel tapes, however, either in the standardization or on the measures, or on both, is not only possible, but probable.

Part of these discrepancies may be due to the wind effect on the

tapes. Owing to the twisting of the invar tapes, they present a little of the flat surface to the wind, thus making them more sensitive to breezes than the steel tapes. A careful inspection of the various measures with a view to finding some effect of this character failed to develop anything, as the other errors were large enough to cause these small errors to disappear in the separate sections.

Discussion of Errors.—The results of measurements with tapes and the discussion of their principal errors have been so fully treated in Appendix 8 of the Coast and Geodetic Survey Report for 1892, that it is unnecessary to consider them herein.

The effect of errors due to faulty alignment, both vertically and horizontally, have been eliminated, as previously mentioned, particularly as they are, to some extent, of a compensating character.

The errors caused by faulty tension, although small and partly compensating, are not so completely so as may be desirable. The working balance was usually compared with the two standard balances just before beginning a day's measure and after its completion, particularly if any change were suspected, or if the balance had received unusual handling. It was also frequently suspended by its own hook and its reading noted to see whether the hand had shifted on its pivot, especially after it had received a sudden jerk from any cause.

A change in the working balance of 25 g. (one of the smallest divisions of the dial) was noted occasionally, but no correction was applied to the results for such small errors. They were more or less compensating, and their effect very small. Observations made upon two invar tapes to determine the effect of small changes from the 15-kg. tension gave 0.04 mm. as the effect for a tape length, or 0.8 mm. per km. for a change of 25 g. in tension. The effect upon the steel tapes was considerably less, because they have less mass per unit length and, therefore, less sag under a given tension.

During the work of standardization, the true 15-kg. tension was held very closely, but on the field measures it was impossible to hold it within 25 g. every time. Errors from this source were of the compensating class, however, and their effect on the total length of a base was probably small.

Errors in marking tape lengths are also compensating to a great extent. The graduation mark of the tape was always in the same plane as the copper marking strip on the post, and a tape length was

marked on this copper strip by a line drawn in prolongation of the graduation line. If there were any constant parallax with either observer, it was eliminated in the double measure of the base, as the observers stood on the same side of the posts in all the measures, the two measures always being made in opposite directions.

When preparing the base line, all posts were made solid before leaving them, using braces if necessary to accomplish this purpose. Care was taken to prevent any one from stepping near a post which was holding a measure, hence errors caused by unstable posts were probably negligible, being more or less compensating. No strain was placed on a post, except that necessary to make the mark, which was perpendicular to the base line and not likely to affect the length, especially as the force required was small.

One of the principal sources of error with the steel tapes is the determination of the actual temperature of the tape at the instant of the measure. When the work is progressing rapidly, the tape is moved through the air at a height above the ground two or three times as great as when it is in position for the measure. The time spent in moving from post to post is greater than that necessary to make the measure, hence the tape and thermometers are subject to the temperature of the air at the height of the movement more than at the height of the measure. The temperature near the ground is frequently quite different from that of the air, hence the temperature acquired during the movement is not that of the measure. The tape probably assumes the temperature of its position much more quickly than the thermometers, consequently the thermometers fail to give the actual temperature of the tape at the instant of measure. The fact that the thermometer did not give the temperature of the air in the position of the measure was frequently noticeable when a delay was necessary, as, for example, to measure a set-up. The thermometer would read practically the same while the work was progressing without interruption, but would jump a few tenths of a degree every time a delay occurred, and then return to the original reading as soon as the regular movement was resumed. Errors of this class were more prominent with the steel measures at night than with the invar work in daylight. The temperatures were much more irregular during the day work, of course, but the change during any delay was rarely greater than the usual changes when the work progressed without interruption. In any case,

it was much less than twenty-eight (the ratio of the coefficients of expansion of the two metals) times the temperature differences obtained with the steel tapes.

Cost.—The total cost of the measurement of these six base lines was approximately $7 000, which is at the rate of $116 per km. This includes the cost of standardization, both in the field and at the Bureau of Standards, all expenses of travel and transportation for party and outfit, cost of computations and preparation of results for publication.

If invar tapes only had been used on these measures, the field standardization would have been unnecessary, thereby reducing the cost very materially, probably to less than $100 per km.

The cost of the preparation of the last three bases was $24 per km. The various operations on the other bases were so interwoven that the cost of the different parts cannot be separated.

Advantages of Invar Tapes.—The principal advantages of invar tapes over steel tapes, developed from this season's work, may be summed up as follows:

Invar tapes may be standardized at the Bureau of Standards instead of in the field, thus effecting a very material saving in both time and money.

The measures with invar tapes may be made in daylight instead of at night, as required with steel tapes, thus increasing the speed and accuracy of the work and further reducing the cost. One objection to the use of the tapes at night is that the moisture from the atmosphere condenses upon the tape and thermometer, increasing the weight of the former and causing the latter to give temperatures which are not as accurate as could be desired. Although errors from this latter source were very noticeable on parts of the measures they were never large enough to warrant a re-measure or a delay of the work.

Owing to the very small coefficient of expansion of the invar tapes, the effect of errors in the determination of the temperatures of the tapes is much less for the invar tapes than for the steel tapes, even though the former are used during the day and the latter at night.

The invar tapes require a little more care in their manipulation than the steel tapes, in order not to bend them to a radius of less than about 8 in. They are a little more sensitive to wind effect than the steel tapes, as the flat surface is frequently twisted considerably from the horizontal plane when in use.

As already stated, steel tapes, when used at night and standardized in the field under conditions similar to those obtained on the measure, give results of the same order of accuracy as bar apparatus and with about one-third of the cost. The results obtained on these six base lines show that invar tapes give much more accurate results than steel tapes, and are also more economical. Consequently it may be stated that, if the iced-bar apparatus is excepted, the use of which is too expensive for the measurement of base lines, the invar tape is the most economical and accurate apparatus for the measurement of primary bases.*

* A more detailed account of this work will be published in the Coast and Geodetic Survey Report for 1907, which may be obtained about January 1st, 1908, by those interested, on request to the Superintendent of the Coast and Geodetic Survey, Washington, D. C.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

WATER SUPPLY.

An Informal Discussion at the Annual Convention, July 10th, 1907.*

SUBJECT FOR DISCUSSION:

"Is it better policy to purchase and control water-sheds, thereby preventing the pollution of impounding reservoir supplies, or to suffer a certain amount of pollution of such supplies, relying upon filtration to correct the effects thereof?"

BY MESSRS. S. BENT RUSSELL, M. R. SHERRERD AND F. W. BLACKFORD.

S. BENT RUSSELL, M. AM. SOC. C. E.—It is evident from this discussion that the question as to which procedure is the better policy cannot be met with an answer so simple and direct that it will not need much explanation and limitation as to conditions. Mr. Russell.

Mr. Fuller has set forth in an admirable way the facts which enter into the problem. He has weighed them in an impartial spirit, and his conclusions, for the most part, seem to be logically drawn. To the speaker, however, it would seem that part of his first conclusion has not been fully demonstrated in his argument. It may yet be shown that, with equal intelligence and watchfulness, the purchase and control plan is equally as efficient as filtration, with regard to the sanitary character of the water. The cases referred to by Mr. Snow will bear this out.

The other part of this conclusion—that in regard to the physical condition of the water—is undoubtedly sound, and is a very strong

* Continued from September, 1907, *Proceedings*.

Mr. Russell. point in favor of filtration. This advantage will usually outweigh the detrimental factor of sentiment against impure water artificially made pure. The truth of this has gained more general credence with the growth of the science of water purification.

To make the involved point more clear, compare two towns, one with a water-shed owned and controlled, the other where a certain amount of pollution is allowed, but filtration is in use. Which has the better water supply? This is still a debatable point among engineers; some favor the former, others as strongly the latter. Either plan will give reasonable safety from water-borne diseases, provided intelligent care is exercised in the management. It might be said, as in the matter of forms of government:

"* * * let fools contest,
That which is best administered is best."

With good administration, the former town will have the better supply, from the point of view of one who thinks a naturally pure water is better than a purified water; while the latter town will be better protected usually against objectionable tastes and odors and visible impurities, as shown by Mr. Fuller. It may be remarked that a majority of water consumers do not inquire into the purity of the supply, if the water is clear and sweet. On one side, therefore, it is found to be a matter of sentiment or prejudice in favor of water naturally free from sewage pollution; on the other, that of prejudice against water which is at times objectionable to the senses. The speaker believes that of late years progress has been in favor of filtration.

If it is admitted that there is no great balance of advantage in favor of either plan as regards quality, the question of cost may then be taken up. At the final test a community usually wants a satisfactory water at the lowest cost. Any further expenditure must be more than justified, in money value, by the superior quality. It must be recognized, as Mr. Clarke says, that the financial question is often a controlling factor. Mr. Fuller shows that, in the matter of cost, filtration has the preference. In any given case, however, the cost will depend upon local conditions, and, therefore, the procedure must be governed by these conditions. Among the local conditions, existing laws and customs, as affecting sanitary control, must be considered.

Mr. Fuller states that there is need for better legislation regarding sanitary matters, and Mr. Snow shows most clearly what proper legislation can do for the protection of water supplies. This brings us to the broad question of proper legislation for controlling the disposal of sewage and wastes, and the pollution of lakes and streams. The speaker understands that, in the matter of such legislation, many of the States, and the United States, as a whole, are sadly behind the best practice of European countries.

Mr. Russell.

These, of course, as far as pertains to the United States, are all questions of the future. Engineers are now working toward the adoption by the Government of wise laws for the protection of future generations against the dangers that will come with increased population, and they should continue in this work with still greater zeal and co-operation. Such laws are required by true public economy in the matters of sanitation and water supply. Proper legislation will reduce to a minimum the expense of protecting the water-sheds.

From these considerations, with a view to future public economy and health, the following may be formulated as an answer to the question under discussion: The best policy is to limit the pollution of the water-shed by suitable legislation leading to proper drainage and disposal of wastes, followed, of course, by vigilant enforcement of the laws, so that they will effect their purpose. This should be supplemented by filtration of such character and efficacy as to produce a satisfactory public water supply, as defined by Mr. Fuller.

In the speaker's judgment, the cases requiring purchase of land instead of filtration would be so few that they could be classed as exceptional.

Whether or not this answer is accepted, all may fairly hope for, and work together for, legislation to protect our streams and lakes from pollution, and for the better observance of sanitary laws by the public.

Mr. Sherrerd.

M. R. Sherrerd, M. Am. Soc. C. E.—It seems as if there might be a middle ground between the views expressed in the discussions by Mr. G. W. Fuller and Mr. George A. Soper, one of which points to filtration as the only means of safety, while the other seems to indicate that filtration is not necessary. It seems to the speaker that proper sanitary protection turns on the point of whether water-sheds can be selected which will be safe without filtration; perhaps it will be essential that, in every case, filtration must be resorted to eventually. It would seem possible, where the population is small and perhaps occupies only a portion of the water-shed, that the installation of a sewer system to take off the waste from that population, which represents the more expensive portion of the water-shed (from the standpoint of purchase), could be resorted to, and that the outskirts, which are generally the cheaper part, should be purchased, so that a combination of sanitary measures would be effective for a great many years. This would certainly be a cheaper method in many cities in the United States than the immediate installation of filtration, and would be also a very satisfactory protection for many years.

One of the discussions referred to the effect of sedimentation, and it might be of interest to give some figures as to the reduction of bacteria noticed in the water supply designed for a population of some 300 000, where the capacity is about 50 000 000 gal. daily. On this

Mr. Sherrerd. plant there was recently constructed a storage reservoir near the city holding about a month's supply. Formerly, the water was brought down through some 25 miles of pipe line, and, at the intake, the bacteria would run as high as 5 000 per cu. cm., and in the tap water of the city it would be reduced, principally due to the absence of light in the pipe lines and sedimentation in the city reservoirs, to an average of 200 bacteria per cu. cm. After the use of the storage reservoirs, where the water is held for about a month, the bacteria being about the same at the point of intake on the water-shed and the conditions being similar, the number of bacteria in the tap water has been reduced to an average of from 20 to 30 per cu. cm., running along at those figures for months at a time.

There is one other feature in the protection of water supplies which seems to be essential and to which more attention will no doubt be paid in the future; that is, the danger of pollution from railroads traversing the water-sheds. It would seem conclusive, and public health authorities have recommended, that stringent laws will be necessary to secure proper sanitation in this respect unless the railroads see that it is to their interest to provide some sort of sanitary measures. In New Jersey it was proposed that they should go even so far as to enact legislation which would put this matter in the hands of the State Board of Health. This was done at the suggestion of some of the local authorities who were interested in the matter, and at least one railroad has agreed to close the closets on the trains while traversing the water-shed of the Newark water plant. This is done also on the New York, New Haven and Hartford Railroad on the New Haven water-shed, and is being done on the water-shed of the Scranton, Pa., water supply because of an order from the State Board of Health. It was also proposed to do this at Seattle, Wash., on the portion of the road which was to be built through the territory from which that city derives its water supply.

New Jersey has enacted legislation which will allow the cities to provide sewerage facilities for the drainage of the population on water-sheds where the State Board of Health creates a district, and the State Sewer Commission approves the plans. The cities are to pay for the installation of these systems.

To insure that the sewage be treated properly before it is discharged into the stream, it is proposed, on the plan to which reference was made, that a sewer system shall be installed with septic tanks, and that broken-stone sprinkler filters and fine sand filtration shall be resorted to before the outfall discharges into the main stream below the intake. This act provides that, while the city shall pay the entire cost of installation, it may have the authority to enter on private property and cause connections to be made from outhouses or closets to the sewer, and provide proper sanitary arrangements; and it is also pro-

posed that a water supply shall be installed from one of the reservoirs in order that the sewer may be flushed properly. Mr. Sherrerd.

In the speaker's judgment, the purity of the water supply for this particular city will be insured, at least for a great many years. There is one question, however, which is troublesome, namely the fact that by the installation of such a system, particularly in the neighborhood of a suburban section of the metropolitan district around New York, the property, to a certain extent, is made more desirable for residence purposes, particularly for villa sites where people from the metropolis may have all those advantages, so that this has, in a measure, a tendency to increase the population of the district. On the other hand, to attempt to secure by purchase the tracts of land that are necessary to protect a water supply is usually much more expensive than the cost of installing and maintaining adequate sewerage facilities.

The conclusion of the speaker is that conditions must always govern, and that it is essential that the purest water should be obtained primarily; its treatment will depend on circumstances.

F. W. Blackford, M. Am. Soc. C. E.—This question is largely one of economics, and should be considered like any other problem that comes before an engineer. Local conditions make a great difference in such propositions. In populous districts, like those adjoining New York, and in Pennsylvania or New Jersey, and other places similarly situated, it might be impracticable to acquire a water-shed entirely, but in many places it would be practical. Of course, this depends largely on the ability of the community to tax itself sufficiently to obtain a large water-shed or one of sufficient size to furnish a supply, but it is a question of locality and a question of making figures, like other propositions, such as building railroads and adjusting the grades and curves to the amount of money available, and to the traffic which is expected. In many places, even in populous districts where the water supply is drawn from a distant point, a large tract of land could be acquired and controlled absolutely. It does not follow that such land should remain useless; it could be planted in grass or in forest—more properly in forest, which, in the course of a generation, would become profitable; and, while it might also be found necessary to filter the water to some extent, the circumstances might be such that it would not have to be filtered at all. It is an economic proposition, and one should consider the amount which the community under the law could tax itself, the amount of income to be derived, the operating expenses, etc., as against the fixed charges. Mr. Blackford.

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PAVEMENTS.

An Informal Discussion at the Annual Convention, July 10th, 1907.*

SUBJECT FOR DISCUSSION:

"Will the paving materials of the present be used in the construction of the pavements of the future?"

BY NELSON P. LEWIS, M. AM. SOC. C. E.

Mr. Lewis.

NELSON P. LEWIS, M. AM. SOC. C. E.—This question, as the speaker understands it, is calculated to invite discussion or speculation as to whether or not the popular, successful pavement of the future will be one of those now generally in use, or whether something new will be evolved or developed. Almost every pavement is an evolution. An interesting thought has been brought out concerning another cheap bituminous pavement consisting of asphalt laid on, or mixed with the ground. Here is a reversion to the discovery of the adaptability of asphalt for street pavements or road surfaces. The rock asphalts of Europe being hauled in carts for the purpose of making cistern linings, it was found that material which dropped from the carts, when mixed with the natural road material, formed a smooth, elastic and excellent roadway. This was probably the first asphalt pavement, and observation of the effect of the accidental deposit of asphalt on this road led to the construction of the first European rock asphalt pavement; and, after half a century, we are going back to this accidental type of roadway which brought about the development of the present asphalt pavement. This shows that, after all, bituminous pavements are the result of discovery and chance as well as of evolution.

*Continued from September, 1907, *Proceedings*.

Mr. Lewis.

In the speaker's judgment the great trouble with the development of a new paving material is the disposition of the contractor or discoverer to exploit it before he understands it thoroughly. Reference has been made to wood pavements, beginning with the Nicholson block, made of the cheapest material and laid in the most indifferent way. Several cities in the United States had very unfortunate experiences with this pavement, one becoming practically bankrupt through laying large areas of these short-lived blocks. In America this gave wooden pavements a black eye for years. There is now a revival of wooden pavements, and there are evidences of the same disposition to exploit them by laying as many yards as possible at as good a price as can be secured through any influence that may be available. The greater the area laid, the more indifferent seems to be the workmanship, and the less care seems to be given to the selection of material, so that it will occasion little surprise if this material, which is capable of making an admirable pavement, is abused to such an extent that there will be a reaction against it in a very short time.

The adaptability of asphalt has been marvelous; it is found in successful use from Manitoba to the Tropics; in the severe frosts and storms of the North, and in the hot, moist atmosphere of the South. Under the conditions prevailing in the City of Mexico it seems to be admirable, and it is difficult to conceive of a pavement which could be more satisfactory than the asphalt pavements of that city. After all, the real value of a pavement is not determined wholly by its wearing qualities. Its appearance is a most important consideration, and at present there is no material that can be kept so neat and so immaculately clean as asphalt under an efficient system of street cleaning. This is admirably illustrated in the City of Mexico; the speaker cannot recall ever having seen asphalt pavements in better condition, or cleaner, than those laid on the principal streets. In walking to the Mineria, the speaker had a few scraps of paper in his hand, which he tried to dispose of; he had not the temerity, however, to throw them on the streets, which were perfectly clean, so he carried them into the building where he disposed of them. The City Government is to be congratulated upon its ability, not only to lay pavements of this kind well, but to keep them clean and maintain them very thoroughly. The officers in charge of street cleaning in northern cities might profitably visit the City of Mexico for an object lesson.

The selection of the kind of pavement is, after all, what might be called a question of luxury, as has already been said; how good a suit of clothes can a man afford to wear? Imagine the effect, on the rental value of an office building, of a clean pavement from which the dust will not be licked up and blown into the windows by every breath of wind, or of a pavement which is fairly noiseless. If distributed over that rent roll, the money required to renew such a pavement, if

Mr. Lewis. necessary, every three or four years, would be trifling. It is this luxury for which the people of London are willing to pay; the pavement in general use there is not permanent; it has to be renewed every few years, but it is clean and quiet; and the people are willing to submit to the inconvenience of its frequent renewal.

Block pavements are frequently urged and advertised, because they can be repaired so readily; but the argument is fallacious. There is no pavement that can be repaired as readily as modern artificial sheet asphalt pavement. If blocks are removed, they can never be laid as perfectly as they were originally, and when the true surface is gone, the blocks readily deteriorate. There is a disposition to relay the old blocks when they are not badly worn, but, with the sheet asphalt pavement, the material put in is new and has the same life as the original pavement. By the time the pavement is 10 or 15 years old, with the many frequent openings which are unfortunately made, a very large part of it is relatively new. This constant reopening of pavements is annoying and most exasperating, and it is to be hoped that some way will be found to avoid it. As far as the pavements of the future are concerned, the speaker can see nothing to indicate that there will be anything new. As Mr. Tillson has said, almost every material has been tried—glass, straw, iron, wood—almost every elementary substance, and every mixture which ingenuity or imagination can suggest. It is quite probable that the pavement of the future will be quite similar to the pavement of to-day, and the speaker knows of nothing which equals, in its universal adaptability, the modern sheet asphalt pavement.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

FOUNDATIONS.

An Informal Discussion at the Annual Convention, July 10th, 1907.*

SUBJECT FOR DISCUSSION.

"(*a*) What is the best system of construction for foundations of heavy structures on ground such as that of the City of Mexico, which is an alluvial deposit about 300 ft. in depth, and similar in character to that at New Orleans?

"(*b*) Will iron or steel used in foundations, independently or in combination with other materials, last indefinitely when in direct or indirect contact with water?

"(*c*) Will the strength and durability of concrete in foundations be affected if before setting there is: (1) an excess of water; (2) lack of compression; (3) too rapid desiccation?"

BY MESSRS. HENRY W. HODGE AND HENRY ROHWER.

HENRY W. HODGE, M. AM. SOC. C. E.—In designing foundations for buildings, there are only three factors to deal with: the loads to be carried, the bearing capacity of the soil, and the friction capacity of the soil. The bearing and friction capacity of the soil can be ascertained by experiment with considerable exactness. It would appear at first that the loads to be carried is the simplest matter to determine, but this is not true, as the moving portion of the load is purely an estimate, and the actual moving loads seldom agree with those assumed. The usual allowance for moving load in an office building is 70 lb. per sq. ft. of floor area, which is taken to be uniform; and in high buildings, the total load does not approximate to an average of this amount on each floor. One of the causes of unequal settlement in foundations of buildings, especially in high buildings where a large total live load has been computed, but which really does not exist, is

Mr. Hodge.

* Continued from September, 1907, *Proceedings*.

Mr. Hodge. due to the fact that the foundations are generally computed for a total consisting of live and dead loads.

The columns carrying the outside walls are computed to carry a very heavy dead load, which is sure; and a comparatively small live load, which is doubtful; whereas, the interior columns are computed to carry a relatively light dead load and a much heavier live load, as the live load can come from all sides to these columns. Consequently, the actual unit pressure under the wall columns is extremely likely to exceed the actual unit pressure under the interior columns, and therefore they settle unequally.

While the speaker agrees with Señor Marroquin that under uniform loads the periphery settles more slowly than the interior, yet, in view of the fact that, for the foregoing reasons, the actual pressure at the periphery is generally greater than the interior pressure, it often occurs that the exterior columns of a building settle more than the interior, and the speaker has seen several buildings in which the outer walls had settled so much more than the interior that the floors had a decided dip from the center in all directions to the walls. It is the speaker's opinion that it would be better engineering practice to calculate all foundation pressures for dead loads only, and set unit pressures at such a low value that they could stand safely the additional weight due to such moving loads as might come upon the building. The speaker is not at all a believer in the practice of building one continuous platform or "raft" as a foundation for a building on compressible soils, as it is impossible to distribute the total load of the building uniformly over such a platform, and the consequence of unequal pressures is that these platforms will break and cause cracks, and in buildings on a street corner where two of the exterior walls are of stone, and of considerable thickness in order to give the necessary architectural appearance, whereas the remaining two walls are of skeleton construction, the increased weight on one side of the platform foundation is often such as to tip the whole foundation and throw the building out of plumb, as has been done in the case of some tall buildings in New York City.

In the speaker's opinion, the best form of foundation on yielding soils is a series of small platforms, each independent of the other, and each proportioned for the load coming directly upon it, so as to make the foundation pressure under all platforms uniform, and, if such a form of foundation is followed, it is not a matter of great importance if settlement does occur, provided the building has been started high enough to allow for this settlement, as there are many buildings now in perfectly good condition which have settled as much as 2 or 3 ft. without showing any serious damage. Of course, on a soil as compressible as that under the City of Mexico, it would be impossible to get area enough under tall buildings to support the building on a series of platforms, and in such a case some form of frictional pile

must be used, and it would appear to the speaker that the sand piles which have been mentioned would fill the conditions excellently. Evidently, there are interstices in the underlying strata which must be filled up, and these sand piles seem to fill in these interstices effectually. It might even be found possible to fill the interstices with cement grout as was done by A. P. Boller, M. Am. Soc. C. E., when he solidified the rip-rap filling under some bridge piers for the New York and Northern Railway, by forcing iron pipes into this rip-rap and pumping cement grout through it until it filled completely all the interstices of the rip-rap, and formed one solid monolith. Mr. Hodge.

HENRY ROHWER, M. AM. SOC. C. E. (by letter).—It is found invariably that water is the principal factor in making soil instable, so that careful preparation is required in order to carry structures of great height. In Louisiana, and also in the City of Mexico, the soil is so permeable that water enters and mixes with it, thus making it loose and slushy. By compressing the ground, or condensing its volume, the water is driven out, and the soil is made capable of greater resistance. Mr. Rohwer.

It is also necessary to drain the soil, but the extent to which this can be done depends on the geological and topographical formation of the surrounding country. If the ground is level, and no underground drainage can be established at reasonable cost or within the limits of practicability, the writer recommends the following proceedings:

First, compress the soil by driving piles after the excavation has been made to conform to the bottom of the basement level, and then construct a flooring capable of receiving and distributing the weight of the building.

Second, collect the water in sumps or wells, and arrange the construction of the floor and foundation in such a way that the weight of the walls will assist in the retention of the ground level within, and *vice versa,* thus preventing the tendency to upheaval in the middle by the pressure of the walls, or the soil and water on the outside which has not been excavated to the same level. This may be done by a flooring of reinforced concrete strong enough to resist the pressure expected, and tied to the walls so that it may be considered as practically a portion thereof, thus making the weight on the walls help the floor to maintain equilibrium.

In both cases the whole area inside the building lines will act as one bearing surface, and the walls with a spread footing will help to make it effective. The first, and cheaper, method may be rendered as effective as the second, if constructed properly.

In applying "pressure piling" the writer has met with marked success, and has compressed ground bearing not more than 250 lb. per sq. ft. so that it would bear more than 3 000 lb. per sq. ft. Some of this work, done in 1888, is still in perfect condition.

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COMPARISON OF RAINFALL AND RUN-OFF IN THE NORTHEASTERN UNITED STATES.

Discussion.*

BY MESSRS. RAPHAEL ZON, C. C. VERMEULE AND H. K. BARROWS.

Mr. Zon.

RAPHAEL ZON, ESQ.† (by letter).—The data on the relation between precipitation and run-off brought together by Mr. Hoyt are of great scientific and practical importance. Unfortunately, the figures apply to large drainage areas. As a rule, these present a complex of conditions which often compensate and counteract each other, and, therefore, obscure the real factors affecting the run-off. In many cases large drainage areas, radically different from each other, yielded practically the same final results, from which general conclusions were often made, which could not be corroborated by observations on smaller water-sheds.

The figures of precipitation and run-off over large drainage areas, each presenting varied conditions, cannot give proper consideration to all factors affecting run-off. Such observations naturally bring out only the general factors, such as precipitation and temperature. Thus Professor A. Penk, one of the best authorities upon the regime of the Elbe, Danube, and other rivers of Middle Europe, by observing the large drainage basins of these streams, came to the conclusion that the annual discharge of rivers depends only upon temperature and precipitation; and that the ratio of the run-off to precipitation on water-sheds of radically different character remains the same, namely, the run-off constitutes about seven-tenths of the precipitation above a certain minimum (420 mm.). If the precipitation were to fall below this minimum, there would be no run-off.

* Continued from September, 1907, *Proceedings*.

† Chief, Branch of Silviculture, Forest Service, U. S. Dept. of Agriculture.

Mr. Zon. Mr. Newell found about the same ratio for the drainage basins of North American rivers. According to Mr. Newell, the minimum precipitation, above which run-off takes place, is 300 mm., and the run-off is equal to eight-tenths of the precipitation above this minimum. Investigations on small catchment areas show that the relationship between precipitation and temperature, on one hand, and run-off, on the other, is not so simple. On small water-sheds where the different conditions may be accounted for, the effect of other factors is much plainer than on large drainage basins, and therefore they are apt to yield more reliable results.

Besides precipitation and temperature, the vegetative cover of the water-sheds, especially the forest cover, affects the quantity and the character of the run-off. It is a well-established fact that the quantity of water available for stream flow from forested water-sheds, all other conditions being equal, is less than from non-forested water-sheds, and it is clear why it must be so. The amount of precipitation which reaches the soil in the forest is always less than that which reaches the soil in the open, because of the interception of a part of the water by the crowns of the trees. The quantity of soil in the forest varies with the species and age of the trees, and the development of the crowns and the kind of foliage. Light rains are almost totally intercepted by the crowns without reaching the soil; the heavier the rains, the more water reaches the forest soil. The amount of precipitation which is lost in this way for the forest soil is greater in coniferous than in broad-leaved forests. It is equal to 20% of all the precipitation in a hard-wood forest; in a thin coniferous forest it is 30%, and, in a dense spruce forest, it is from 30 to 45 per cent. For this reason, coniferous forests, although they transpire less water than broad-leaved forests, demand a climate with heavier precipitation, mountain slopes, for instance, or soils with a greater water-carrying capacity, preferably sands.

Besides the interception of precipitation by the crowns of trees, a loss of moisture on the way to the soil is also occasioned by the forest litter, which absorbs part of the water reaching the forest floor. According to Wollny's experiments, a layer of litter 5 cm. deep, composed of leaves and needles, and exposed to sun and light, allows only from 64 to 70% of all the precipitation that falls upon the forest floor to reach the soil, and only 53% reaches the soil through a layer of moss of the same depth. Thus the forest soil receives the least precipitation, next comes meadow land, and lastly tilled land.

In the forest, only the upper layer of the soil is moister than in the open, the lower layers being always drier. Thus, according to Ebermayer's experiments of 1884-86, the percentage of soil humidity at different depths in an uneven, aged, spruce forest and in the adjoining field is as shown in Table 7.

Mr. Zon.

TABLE 7.

Depth.	Young forest, 25 years old. Percentage.	Middle-aged forest, 60 years old. Percentage.	Mature forest, 120 years old. Percentage.	Field. Percentage.
0- 5 cm.....	28.97	20.48	40.25	22.33
15-20 "	19.19	19.07	19.29	20.62
30-35 "	19.10	16.07	18.29	20.54
45-50 "	18.39	16.26	20.22	20.24
75-80 "	18.00	17.90	21.12	20.53
Average....	16.67	17.32	19.73	20.23

The middle-aged forest always produces the greatest desiccation of the lower layers of the soil. This is especially noticeable in summer and fall. In such a forest the soil humidity at a depth of 40 cm. is, on an average for the summer, 15.12%, while in the field at the same depth it is 19.89 per cent. The dryness of the soil under the forest is caused by the transpiration of water by the forest. Since trees produce more organic substance per unit of area than other plants, their expenditure of water for the formation of cells, therefore, must also be greater. The enormous transpiration of water by the forest and the smaller amount of precipitation received by the forest soil cause the greater dryness of the soil under the forest.

All this goes to show that the forest cover tends to decrease the total quantity of water available for stream flow. A comparison of forested and non-forested water-sheds, especially in the South, would probably show a smaller total amount of run-off from forested, than from non-forested, water-sheds. It would also show, however, a difference in the distribution of the run-off throughout the year, and throughout a cycle of dry and wet seasons. In all cases, the forest tends to decrease the difference between the maximum and minimum run-off, and to maintain a steady flow of streams. This is very clearly shown by Professor Toumey's investigation in the San Bernardino Mountains of Southern California. Here the run-off during the dry summer months was maintained in the forested areas, while, over an unforested area, under the same conditions, there was practically no run-off during the summer. The data concerning precipitation and run-off, as brought out by Mr. Hoyt, while true for average conditions, such as exist over large drainage basins, may not be applicable to smaller streams and water-sheds where there is a lesser variety of conditions which compensate each other, and, therefore, other factors, besides precipitation, are at play.

Mr. Vermeule. C. C. VERMEULE, ESQ. (by letter).—While there has been accumulated a large addition to the records of stream measurements in the United States during the past ten years, the writer has not yet found it possible to ignore the effect of differences of rainfall, temperature,

cultivation and soil conditions in computing the run-off of any stream for which gaugings do not exist and for which he finds it necessary to have the most accurate estimate of run-off which can be made. Mr. Vermeule.

The differences in run-off of streams in the same region are so great that to apply directly the gaugings of one stream to some other stream, without correction, must be regarded as unscientific and unsatisfactory. If we have not at hand accurate measurements of precipitation upon the two streams covering a considerable number of years, we may be unable to do better, but with measurements of precipitation and of temperature, and an examination of the respective water-sheds, carefully noting differences in soil conditions, topography, forestation and cultivation, the hydraulic engineer of experience should be able to make a much closer approximation to the run-off by properly correcting a set of gaugings to allow for these differences. Such correction can only be made after one has familiarized himself with the phenomena and the laws which govern the relation between rainfall, temperature, topography, soil conditions, and the run-off of streams. A patient and careful analysis of such data has brought the writer to the firm conviction that the greatest need is that certain typical streams throughout the United States, comparatively limited in number, should be gauged with a high degree of accuracy, with simultaneous rainfall measurements at a number of well-selected points upon their water-sheds, and that these gaugings should be continued over a considerable period. The same money expended in gauging a very large number of streams in an indifferent manner, without careful simultaneous rainfall records, if expended upon more careful measurements of one-tenth of the number of streams selected as typical water-sheds would do far more to reduce hydrology to a science.

In studying the relation between rainfall and run-off, it is necessary to keep in mind the fact that the run-off is merely the difference between the rainfall and the evaporation taken in its broad sense to include the water taken up by vegetation as well as that directly evaporated in the atmosphere. Under ordinary natural conditions, the water which percolates downward and does not reappear through springs is insignificant in amount. Evaporation obeys well-known laws which have been the subject of much study and investigation, so that there is much at hand on which to base a reasonable method of computing it. It is to a large extent a function of the temperature. Having the rainfall for a given period, if the evaporation for the same period could be computed, the difference should represent the run-off, and it will be found to do so, nearly, if the period in question begins and ends with the free ground-water at substantially the same level. In actual experience, however, it will be found that, with the same amount of rainfall, the run-off may vary in different years from about 37% to about 63% of the rainfall, or as much as 10 in. per

Mr. Vermeule.

annum. Under such conditions, the scientific mind cannot be satisfied to proceed with any rule-of-thumb method, or with any method which does not allow for such variations. This particular difference is due to the water taken up by the ground and stored therein, to be fed out to the streams later during the dry season, and it illustrates the very important effect of soil and sub-soil conditions in maintaining the dry-season flow and equalizing the yield of the stream.

About 1890 it became the writer's duty to make as accurate an estimate as possible of the run-off of the streams of the State of New Jersey. This, at that time, had become urgently necessary, and there was no time for extended gaugings of streams. Gaugings were made to a very considerable extent during the four years of work, but much reliance had to be placed upon the longer series of measurements then available upon the Sudbury, Connecticut, Croton, Tohickon, Neshaminy and Perkiomen. Through the courtesy of the Dundee Water Power and Land Company, the writer was also fortunate enough to obtain a 17-year record upon the Passaic. A study of these records showed a marked resemblance between the Sudbury, Croton and Passaic, so striking on close analysis that it was found that these three streams exhibited a quite well-defined relationship between rainfall and run-off. After plotting the results, a formula was deduced to cover this relation, but it soon became evident that the data exhibited by these measurements could not be used as applicable to other streams in New Jersey without correction. This led to the application of a correction, due to differences of evaporation, which was found to increase and decrease with the temperature, and a further correction which followed for differences in topography and soil conditions, or, in other words, the varying effect of ground storage.

Later, in 1899, while investigating the effect of forests upon stream flow, the writer utilized additional data then available covering thirty-four streams in the Eastern United States, extending from the Merrimac on the north to the Savannah on the south, together with a few in the Mississippi Valley and four in England. Giving these results weight in accordance with the length of the record and the known reliability of the rainfall and run-off measurements, a more accurate formula for computing the evaporation from the rainfall was deduced.* The results given by this formula agreed with the observed results upon seventeen streams having an average length of record of 12 years, in all cases within 5%, the mean error being only 1½ per cent. Three more streams, with records averaging 11 years, vary from 6 to 8%, and the remaining fourteen streams, having shorter records, averaging 6.5 years, show wider differences, the average discrepancy being 5 per cent. These results, together with later experiences, have convinced the writer that it is possible to evolve a formula and method of computing run-off from rainfall which, generally speaking, will

* Geological Survey of New Jersey, Annual Report for 1890, p. 148.

give results far more reliable than can be obtained either from adopting figures of run-off on other streams without correction, or from gaugings upon the stream in question if they do not extend over a longer period than 5 or 6 years. One has only to examine any reliable record, such as that of the Sudbury, in order to be warned that gaugings which extend over only one or two years may vary so widely from average experience upon any given stream as to be not an aid, but possibly a hindrance, to good judgment. Short series of gaugings may be very valuable, if used properly, that is, by taking into account the rainfall during the period together with the average rainfall, and the rainfall for the driest years upon the same water-shed. Here, again, one must know with reasonable accuracy the true relation between rainfall and run-off. Mr. Vermeule.

Personally, the writer has never found much use for percentages in the computation of run-off. If percentages are determined from average rainfall and run-off, they are only applicable to a fictitious average year, or a year which never actually occurs in Nature. Examine any extended run-off measurements, and it will be readily discovered that, during many months in which little or no rainfall occurs, the stream will continue to discharge a considerable quantity of water. This makes it evident that there is no direct relation whatever between the run-off in any given month and the rainfall for that month. This does not refer to winter when the precipitation is locked up in snow, but to the dry hot months in summer. For water-power purposes the writer has of late been able to obtain excellent results by taking gaugings covering a long period upon a stream on which the topography and soil conditions are similar to the one for which he is estimating, and determining by actual count the number of days during which this stream stood at or above given stages of flow, and then plotting the results in a diagram. Having done this, he determines as accurately as possible, from the records of the United States Weather Bureau, the average rainfall and temperature upon this stream during the period covered by the gaugings, and then determines the same data for the stream to be estimated; next, he computes the evaporation and run-off for each stream, and increases or decreases the stages of flow in the proportion that the run-off upon the measured stream bears to the run-off of the stream to be estimated, plotting a corrected curve for the stream to be estimated. Where this method has been adopted and afterward compared with the records of water-power owners upon the stream, a close agreement between the two has been found.

The accurate computation of run-off is useful mainly to determine the amount of storage needed to maintain a given yield, or the amount of water-power to be obtained upon a given stream. To some the whole subject may seem to be largely academic, but, not only is it of importance for the purposes indicated, but the relation between rainfall and run-off is of general scientific interest, and bears upon the

Mr. Vermeule. subjects of forestry, sub-soil drainage, irrigation, etc. While it is a study which requires more time and closer application than can usually be given to it by an engineer in active practice, this is the best reason why we should the more readily encourage every attempt to elucidate the subject and to simplify and improve the resulting formulas and conclusions.

The time when there will be at hand reliable and adequate gaugings of each stream one is called upon to develop is still far distant. Meanwhile, there is need to know how to compute scientifically from the meteorological data now so generally available.

Mr. Barrows. H. K. BARROWS, ASSOC. M. AM. SOC. C. E.—The speaker wishes to comment briefly on several points in Mr. Hoyt's interesting and instructive paper, especially on the matter of accuracy of methods in use by the United States Geological Survey.

The Geological Survey has given much attention to the accuracy of both field and office work in stream gauging, and every effort, consistent with the general object of this work, has been made to obtain data relating to or confirming its accuracy. Some of this information has appeared in the Water Supply Papers, already published, while many additional unpublished data have been obtained by the various district hydrographers.

Previous to 1906 the progress reports of stream measurements contained no comments regarding the accuracy of estimates of flow. In the report for 1906, however, an attempt has been made to ascribe to each gauging station an accuracy factor—in many cases varying with the time of the year. The general remarks relating to this factor are:*

"In order to give engineers an idea of the relative value of the various data, notes in regard to accuracy are given as far as possible. This accuracy depends on the general local conditions at the gaging stations and the amount of data collected. Every effort possible is made to so locate the stations that the data collected will give a high degree of accuracy. This is not always possible, but it is considered better to publish rough values with explanatory notes rather than no data.

"In the accuracy notes the following terms have been used, indicating the probable accuracy in per cent. of the mean monthly flow. As these values are mean values, the error in the value for the flow of any individual day may be much larger.

"Excellent indicates that the mean monthly flow is probably accurate to within 5 per cent.; good, to within 10 per cent.; fair, to within 15 per cent.; approximate, to within 25 per cent."

Mr. Merriman especially criticises the current-meter gaugings of flow and the results obtained with the small Price current meter, but agrees that the unbalanced errors of gauge-height observation in monthly mean discharge will be small. In the speaker's opinion, the current-meter gaugings—and therefore the discharge-rating curves—

* Water Supply and Irrigation Paper No. 201, p. 12.

constitute the most reliable part of these data. Mr. Hoyt has shown one example of these rating curves, from the great number that exist, and it is quite unnecessary to call further attention to the remarkable consistency of the current-meter measurements in their relation to the discharge-rating curve. Mr. Barrows.

What the absolute errors are can only be determined by comparison with some other standard of measurement—sharp-crested weirs, measuring tanks, etc.—but, thus far, such comparisons as have been made indicate that a carefully made current-meter measurement at the ordinary gauging station will give results far within the degree of accuracy required in such work.

At one of the gauging stations of the Geological Survey, *viz.*, Little River, at Blandford, Mass., it has been possible during a portion of the past year to maintain a sharp-crested weir just below the regular station, thus enabling a direct comparison of results by these two methods of measurement. These are given in detail in Water Supply Paper No. 201, pp. 105-110, but a summary of results by months will be of interest, and is given in Table 8.

TABLE 8.—MONTHLY MEAN DISCHARGE OF WESTFIELD LITTLE RIVER, NEAR BLANDFORD, MASS., 1906, AS DETERMINED BY WEIR AND CURRENT-METER RATINGS.

Month.	Discharge in Cubic Feet per Second by		Percentage of difference as regards discharge by weir.
	Weir.	Current meter.	
August (10-31)	12.3	13.0	+5.7
September	9.1	9.0	−0.9
October	42.2	42.9	+1.7
November	55.7	57.6	+1.6
Average for period			+2.0

While the daily discharge by these two methods exhibits a considerable percentage of variation at times, the monthly means, and even the weekly means, are remarkably close in agreement. Furthermore, this gauging station is what would be classed as only a fair station—the stream bed being very rough. The differences in this case are evidently mostly due to errors or inaccuracies in gauge readings. It will be noticed, further, that the differences at some times are positive, at other times negative.

Mr. Hoyt's paper deals solely with large drainage areas where the average rainfall is fairly well determined. Information is frequently needed about rainfall and run-off from small drainage areas—perhaps from 10 to 50 sq. miles—such as frequently have to be considered in

Mr. Barrows.

TABLE 9.

	Run-off, in Inches, on Drainage Area, for the Period Given.														
	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	The Year.	Rainfall for the year, in inches.	Percentage of run-off for the year.	Total loss for the year, in inches.
Kennebec River, at Waterville, Maine, 1888-1905, inclusive, 4 270 sq. miles...	0.77	0.77	2.34	5.90	4.96	2.44	1.88	1.04	0.78	0.80	1.09	0.93	23.70	39.63	0.60	15.93
Cobbosseecontee Stream, at Gardiner, Maine, 1891-1905, inclusive, 240 sq. miles.....	1.13	1.11	3.19	3.03	1.81	1.20	1.08	1.13	1.00	0.91	0.83	0.97	17.39	42.18	0.41	24.79

procuring a municipal water supply. In such cases the storage area of tributary ground-water may depart considerably from the topographic limits of the drainage basin and markedly affect the low-water flow per square mile. Local areas of high average rainfall may be included—this being especially common upon mountain slopes—so that the run-off per square mile will be much higher than with small drainage areas under ordinary conditions. This last condition is well illustrated by the run-off of small drainage basins in the White Mountain region, New Hampshire,* noticeably that of Israel, Ammonoosuc and Zealand Rivers. Mr. Barrows.

The storage of water by lakes or reservoirs in the drainage basin, if of considerable amount, will modify the run-off in monthly distribution, and may also in the total amount for the year on account of evaporation of the water while being held.

Table 9 shows the rainfall and run-off data relating to the Kennebec River and Cobbosseecontee Stream, Maine.†

The Kennebec River, at Waterville, has a lake surface of about 5% of the total drainage area at that point, and, of this amount, only a little more than one-half is utilized for storage purposes.

Cobbosseecontee Stream has about 9% lake surface, nearly all of which is utilized for storage. While the total run-off for the year is less for Cobbosseecontee Stream, as indicated in Table 9, yet the monthly means do not fluctuate as much, and the unit flow during the low-water season is always greater.

* Water Supply Papers Nos. 97, 124, 165 and 201; also reports of the New Hampshire State Forestry Commission, 1903-06.

† Water Supply Paper No. 198.

Vol. XXXIII. OCTOBER, 1907. No. 8.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

REINFORCED CONCRETE PIPE FOR CARRYING WATER UNDER PRESSURE.

Discussion.*

BY MESSRS. F. TEICHMAN AND J. R. WORCESTER.

Mr. Teichman.

F. TEICHMAN, M. AM. SOC. C. E. (by letter).—To make good concrete pipe, and to make it at a low cost, three things are required: experience, care, and a good apparatus for moulding the pipe. As to the mould used in building the concrete pipes of the Salt River Project, it gave satisfactory results, on the whole, but by close observation of the apparatus in the field, and of the pipe made by the apparatus, the writer (who designed the mould) arrived at the following conclusions:

1.—For a pipe large enough in diameter to allow a man to do the dismantling of the inner mould, no parts of this mould should be pulled along on the inner face of the pipe (as was the alligator). In preference, the dismantled parts of the rear should be forwarded to the front, and should be erected rigidly there. The three reasons against a sliding mould are: The continuous or intermittent pulling ahead of the inner mould or parts thereof (the alligator) is likely to disturb the support of the concrete while setting, thus establishing a weakness in the concrete, or a defective union between the reinforcement and the concrete. Parts of the concrete while setting may adhere to the moving mould, thus making a face that is marred, defective in appearance, and in compactness and density of concrete. The movement of the mould is not under easy control as to alignment, and it is impossible to make, at will, angles in the alignment of the pipe without interrupting the continuity of the work.

* This discussion (of the paper by Chester Wason Smith, Assoc. M. Am. Soc. C. E., printed in *Proceedings* for August, 1907), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

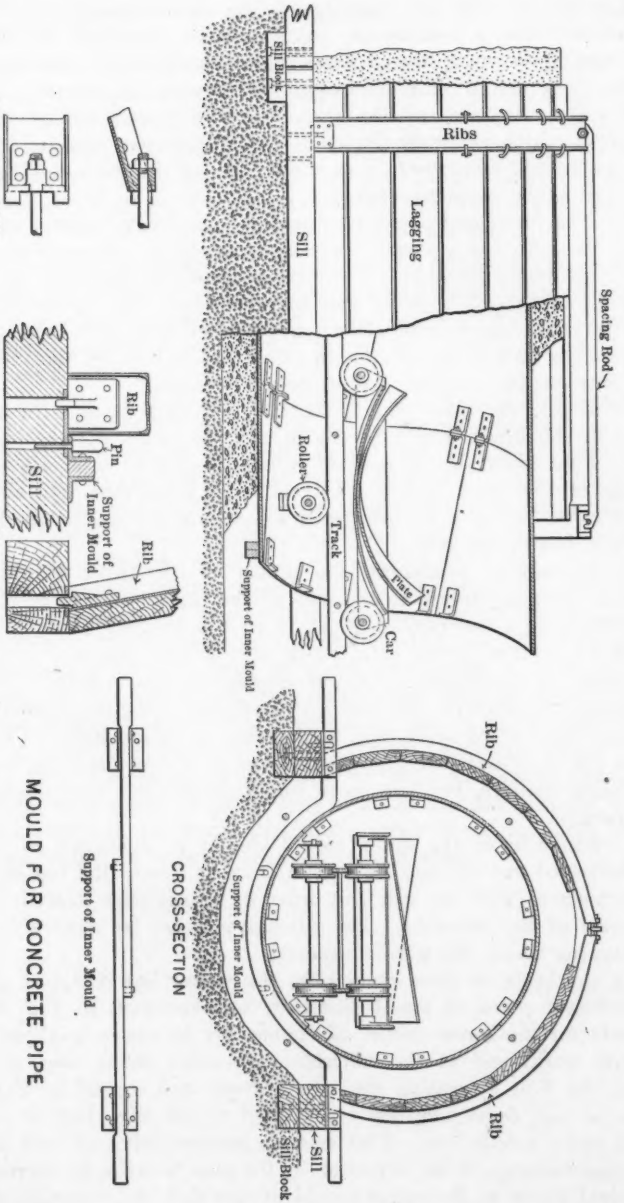

Upper End of Rib
Sill Block
Ribs
Lagging
Sill
Spacing Rod
Rib
Pin
Support of Inner Mould
Sill
Lower End of Rib
Rib
Roller
Track
Plate
Car
Support of Inner Mould
Rib
Support of Inner Mould
Rib
Sill
Sill Block
CROSS-SECTION
Support of Inner Mould
MOULD FOR CONCRETE PIPE

Fig. 5.

Mr. Teichman.

2.—The ribs for the lagging of the outer mould should not be suspended from a framework, but should be supported preferably on sills resting on the ground. The support on sills gives greater rigidity to the outer mould than the suspension from a framework.

3.—The wheeling planks should not be supported by the same structure which supports the mould, otherwise the jars occasioned by the loaded wheel-barrows or cars may be felt in the mould, and this may injure the concrete work.

4.—The inner and outer moulds should be erected on the same base —sills laid on the ground—thus assuring their concentricity. Concentricity makes possible the reduction of the thickness of the pipe to a minimum, and a pipe is cheaper and better, the thinner its walls are, provided the reinforcement is properly embedded and the concrete of the wall is strong enough as a beam to support the inner pressure between two adjoining reinforcement rings.

5.—Inside the inner mould there should be a track with a car, to carry to the forward end of the mould the plates dismantled at the rear. This track should rest on rollers, placed at intervals near the bottom of the inner mould. A track, thus supported, can be pushed ahead at will so as to be always in a convenient position, for both the rear and front plate men.

6.—Instead of arranging the plates of the inner mould in individual courses, square to the axis of the pipe, it is preferable to arrange them in a continuous spiral, in such a manner that their joints, which are square to the spiral, will always be staggered, *i. e.*, strike the plates of the adjoining spiral courses in their middle. For pipe of ordinary diameters, this will give stiffness to the inner mould, even without the use of stiffening angle iron, or brace rods. The spiral plates for a cylindrical pipe mould are as easily made as those for individual courses, but are more easily dismantled and erected than the latter.

7.—The ribs of the outer mould should be arranged so that the two halves of one rib may be spread more or less at the top as well as at the bottom (with the sills), in order to permit some variation in the thickness of the concrete. The rib halves must be removable before any lagging inside the ribs is removed.

On the basis of these principles, the writer has designed a mould for ordinary pipes of small diameter, as illustrated in Fig. 5. The supports for the inner mould, of course, are in use only ahead of the concrete work, and as the concrete approaches them, they are withdrawn (by first spreading the two halves) and moved to the front. While in use, these supports are pinned to the sills, just as the ribs of the outer mould are. This secures concentricity of both moulds. Any slight change in the direction of the pipe is made by leaving open the spiral joints of the inner mould at one side and covering the gap with light iron or tar-paper. At such changes of direction, special

sills and lagging, cut to special lengths, are required for the outer mould. Mr. Teichman

The inner track will accommodate itself to slight lateral changes by connecting the different lengths of track by bolts in slotted holes.

The radial dimension of the supports of the inner mould is small enough so that these supports are always inside the longitudinal reinforcing rods, and the length of the arch of these supports is such that the supports may be withdrawn without interfering with these reinforcing rods, if they are spaced in the usual manner.

J. R. WORCESTER, M. AM. SOC. C. E. (by letter).—The author's experience with these pressure pipes is particularly interesting, in the light it sheds upon the question of the amount of longitudinal reinforcement necessary to prevent transverse cracks in long straight structures. Mr. Worcester

It has been held by some authorities that longitudinal steel to the amount of half of 1% of the area of the concrete is necessary, and it is generally conceded that the proportion is wholly efficient. In underground pipes and tunnels, many have ventured to use considerably less than this, but the determination of the precise quantity has not yet been made, and, in the mean time, all light shed upon the subject is very valuable.

It seems that in the case of the Pinto pipe, the proportion of longitudinal steel to concrete in the portion of the section with cylindrical exterior was about 0.0014. That in one of the pipes of this line there should have been 40 transverse cracks in 2 400 ft., or one to each 60 ft., would not seem surprising, considering the low percentage of steel; and it would seem to be due to an unusual combination of favoring conditions that the other line showed so few.

In the Cottonwood lines, where the ratio of steel to concrete was about 0.002, it would be interesting to know how much of the immunity from cracks was due to the conditions under which the pipes were laid, and how much to the greater percentage of steel.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

(INSTITUTED 1852.)

VOL. XXXIII. No. 9.

NOVEMBER, 1907.

Edited by the Secretary, under the direction of the Committee on Publications.

Reprints from this publication, which is copyrighted, may be made on condition that the full title of Paper, name of Author, page reference, and date of presentation to the Society, are given.

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NEW YORK 1907.

Entered according to Act of Congress, by the AMERICAN SOCIETY OF CIVIL ENGINEERS, in the office of the Librarian of Congress, at Washington.

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ON STATUS OF METRIC SYSTEM:—Stacy B. Opdyke, Jr., John Waterhouse, D. A. Molitor.

ON ENGINEERING EDUCATION:—Desmond FitzGerald, Benjamin M. Harrod, Onward Bates, D. W. Mead, Charles Hansel.

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER.....5913 Columbus.
CABLE ADDRESS....."Ceas, New York."

Vol. XXXIII. NOVEMBER, 1907. No. 9.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

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PROCEEDINGS.

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MINUTES OF MEETINGS.

OF THE SOCIETY.

October 16th, 1907.—The meeting was called to order at 8.30 P. M.; Director George W. Tillson in the chair; T. J. McMinn, Assistant Secretary, acting as Secretary; and present, also, 213 members and 69 guests.

A paper by J. C. Meem, M. Am. Soc. C. E., entitled "The Bracing of Trenches and Tunnels, with Practical Formulas for Earth Pressures," was presented by the author, and illustrated with lantern slides. Written discussions from Messrs. Horace J. Howe, C. W. Birch-Nord, Lazarus White and E. G. Haines were presented by the Assistant Secretary, and the paper was discussed orally by Messrs. F. T. Llewellyn, H. P. Moran, John F. O'Rourke, V. H. Hewes, T. Kennard Thomson, E. P. Goodrich, O. F. Nichols, E. W. Stern, G. L. Christian, W. H. Gahagan, R. A. Shailer, H. B. Seaman and the author.

Adjourned.

November 6th, 1907.—The meeting was called to order at 8.30 P. M.; Director A. L. Bowman in the chair; T. J. McMinn, Assistant Secretary, acting as Secretary; and present, also, 72 members and 14 guests.

A paper entitled "Water Purification at St. Louis, Mo.," by Edward E. Wall, M. Am. Soc. C. E., was presented by the Assistant Secretary, who also read communications on the subject from Messrs. Philip Burgess and Edward Prince. The paper was discussed orally by Messrs. G. A. Soper, G. C. Whipple and L. L. Tribus.

Ballots for membership were canvassed, and the following candidates elected:

As Members.

Alexander Mosby Clayton Byers, City of Mexico, Mexico.
Thomas Wiley Clayton, Shawneetown, Ill.
George Russell Field, San Francisco, Cal.
Frederick Charles Herrmann, Calexico, Cal.
Charles Hanford Kendall, Manila, Philippine Islands.
George Arnold McCarthy, North Bay, Ont., Canada.
Hood McKay, Lansford, Pa.
Jacob Bomberger Rohrer, San Francisco, Cal.
Howard Everett Smith, Albany, N. Y.

As Associate Members.

Frederick William Altstaetter, Pittsburg, Pa.
Emanuel Anderson, City of Mexico, Mexico.
Frederic Herbert Bass, Minneapolis, Minn.
William Bernard Bates, Roanoke, Va.
Philip Asfordby Beatty, Baltimore, Md.
Edward Crosby Bebb, Glendive, Mont.
Maurice Otto Bellingrodt, Atlanta, Ga.
Will Hazen Boughton, Morgantown, W. Va.
Charles Bradshaw, San Bernardino, Cal.
Leonard Dempster Brownell, Syracuse, N. Y.
Robert George Dieck, Portland, Ore.
Samuel Douglass Dodge, Cornwall-on-Hudson, N. Y.
Edward Bowman Espenshade, Roundup, Mont.
Wager Fisher, Philadelphia, Pa.
Percival Morris Fogg, Newlon, Mont.
Philip Guise, Brooklyn, N. Y.
William Cary Hattan, Altapass, N. C.
Guy Frederic Hosmer, Old Town, Me.
Frederick Milton Hough, Saratoga, Wyo.

Anders Jordahl, New York City.
George Israel Oakley, Little Falls, N. Y.
Joseph William Obreiter, Jersey City, N. J.
Henry Garfield Perring, Philadelphia, Pa.
Edward Hawks Ravenscroft, Chicago, Ill.
Warren Fuller Rugg, Peekskill, N. Y.
George M. Stevens, Boston, Mass.
Thomas Patton Stevenson, Rio de Janeiro, Brazil.
Garfield Stubblefield, Hermiston, Ore.
Harry Edward Wagner, Providence, R. I.
Ralph Whitman, Washington, D. C.
Harry Blakemore Wrigley, Philadelphia, Pa.

As Associates.

Robert Anderson, Cincinnati, Ohio.
Henry McBurney, Stockbridge, Mass.
Davis Harrington Morris, Dayton, Ohio.

The Secretary announced:

The transfer of the following candidates by the Board of Direction on November 5th, 1907:

From Associate Member to Member.

Charles Rufus Harte, New Haven, Conn.
James Vincent Rockwell, Mare Island, Cal.
Robert Swan Sumner, Denver, Colo.
Edward Moses Stayton, Independence, Mo.
Guy Bennett Waite, New York City.

The election of the following candidates by the Board of Direction:

As Juniors.

On June 4th, 1907:
Guy Alfred Hersey, Medford Center, Me.

On September 3d, 1907:
Norman Marshall Halcombe, Stanford University, Cal.

On October 1st, 1907:
Arthur Wellesley Coombs, Brooklyn, N. Y.
Reginald Truman Hurdle, Tokna, Mont.

On November 5th, 1907:

FREDERICK LUCIUS COPELAND, Janesville, Wis.
EDWIN LEROY DRIGGS, Lujane, Colo.
THOMAS FLEMING, JR., Pittsburg, Pa.
HEBER GOSSLER GEARHART, Duquesne, Pa.
EVERETT HAMILTON HATCH, Vallecito, Cal.
CHESTER BROOKS LEWIS, Indianapolis, Ind.
HALLET RICE ROBBINS, Albany, N. Y.
SIDNEY DAVIS STRONG, Sault Ste. Marie, Mich.
JOHN RUSSELL VAN HORNE, New York City.
JOHN LEONARD VOGEL, Jersey City, N. J.
GEORGE MERRITT WARD, Hatfield, Wis.
HARRY PERCIVAL WILSON, Boston, Mass.

The Secretary announced the following deaths:

JOHN HOWARD CLARK, elected Member, November 4th, 1903; died October 13th, 1907.

CHARLES EZRA HEQUEMBOURG, elected Member, June 5th, 1901; died October 17th, 1907.

JONATHAN WAINWRIGHT, elected Member, February 3d, 1892; died October 11th, 1907.

Adjourned.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, December 4th, 1907.—8.30 P. M.—Ballots for membership will be canvassed, and a paper entitled "Invar (Nickel-Steel) Tapes on the Measurement of Six Primary Base Lines," by Owen B. French, M. Am. Soc. C. E., will be presented for discussion.

This paper was printed in *Proceedings* for October, 1907.

Wednesday, December 18th, 1907.—8.30 P. M.—A paper entitled "Municipal Sewage Disposal—An Investigation," by J. T. Fetherston, Assoc. M. Am. Soc. C. E., will be presented for discussion at this meeting.

This paper is printed in this number of *Proceedings*.

ANNUAL MEETING.

The Fifty-fifth Annual Meeting will be held at the Society House, on Wednesday and Thursday, January 15th and 16th, 1908. The Business Meeting will be called to order at 10 o'clock on Wednesday morning. The Annual Reports will be presented, officers for the ensuing year elected, members of the Nominating Committee appointed, a proposed amendment to the Constitution presented for action, the Report of the Special Committee on Rail Sections, printed in *Proceedings* of August, 1907, page 290, will be presented for discussion, and other business transacted.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all meetings:

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Society of Engineers, 17 Victoria Street, Westminster, S. W., England.

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Civil Engineers' Club of Cleveland, 718 Caxton Building, Cleveland, Ohio.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa.

Engineers' Society of Western Pennsylvania, 803 Fulton Building, Pittsburg, Pa.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

Louisiana Engineering Society, 604 Tulane-Newcomb Building, New Orleans, La.

Engineers' Club of Central Pennsylvania, Corner Second and Walnut Streets, Harrisburg, Pa.

Engineers' and Architects' Club of Louisville, Ky., 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

Teknisk Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Société des Ingénieurs Civils de France, 19 Rue Blanche, Paris, France.

Svenska Teknologförenigen, Brunkebergstorg 18, Stockholm, Sweden.

Institute of Marine Engineers, 58 Romford Road, Stratford, London, E., England.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Pacific Northwest Society of Engineers, 617–618 Pioneer Building, Seattle, Wash.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Memphis Engineering Society, Memphis, Tenn.

Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

The Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Institution of Engineers of the River Plate, Buenos Aires, Argentine Republic.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Cleveland Institute of Engineers, Middlesbrough, England.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Rochester Engineering Society, Rochester, N. Y.
Brooklyn Engineers' Club, 197 Montague Street, Brooklyn, N. Y.
Montana Society of Engineers, Butte, Montana.

SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

In reference to this work, the Appendix* to the Annual Report of the Board of Direction for the year ending December 31st, 1906, contains a summary of all searches made to that date.

**Proceedings*, Vol. XXXIII. p. 20 (January, 1907).

ACCESSIONS TO THE LIBRARY.

(From October 8th to November 11th, 1907.)

DONATIONS.*

FORMULES, TABLES ET RENSEIGNEMENTS USUELS.

Aide-Mémoire des Ingénieurs, des Architectes, etc., Partie Pratique. Par J. Claudel. Onzième Edition Entièrement Refondue, Revue et Corrigée par de Nombreux Collaborateurs sous la Direction de Georges Daries. Paper, 9 x 6 in., illus., 2 vol. Paris, H. Dunod et E. Pinat, 1907. 30 francs.

The first edition of this handbook for engineers and constructors was published in 1846, since which time eleven editions have been issued. In the preparation of the present volumes, M. Daries has followed the lines originally laid down by the author, being assisted by a number of engineers, each of whom is a specialist in his work. The subject-matter has been thoroughly revised and brought up to date by the addition of new chapters and 868 new figures. Such subjects of current interest as hydraulics, hydraulic motors, the distribution of water, electricity, lighting, steam engines and boilers, steam and gas turbines, roads, bridges, railroads, automobiles, steel construction, reinforced concrete, etc., have received special attention. The formulas and problems are given in a clear and precise manner, and have the added value of having been used in French technical schools and Engineering Departments. The Contents are: Mécanique; Résistance des Matériaux; Hydraulique; Moteurs Hydrauliques; Distributions d'Eau; Assainissement; Physique Industrielle; Electricité; Routes et Canaux; Calcul et Construction des Ponts; Moteurs a Vapeur et a Gaz; Chemins de Fer; Architecture; Matériaux de Construction; Fondations; Constructions Civiles; Appendice. At the end of the second volume there is an index of twenty-eight pages.

STEAM BOILERS AND SUPPLEMENTARY APPLIANCES.

A Practical Treatise on Their Construction, Equipment and Working. By William H. Fowler. Cloth, 9 x 6 in., illus., 12 + 619 + 14 pp. Manchester, England, The Scientific Publishing Company. 12 shillings 6 pence net.

This volume, it is stated, is the result of thirty years' study and practical experience in boiler design, inspection, and construction on the part of the author. In it he has endeavored to supply a book which will prove useful to the steam user, the works manager, the boiler inspector and the man in charge of the boiler alike, and one which will show the relative advantages and disadvantages of a particular arrangement or piece of apparatus and teach not only the "how," but also the "why." The design of boilers, with a brief outline of the strength and properties of materials, as well as the principles of construction, are discussed in the first two chapters. The principal types of boilers and fittings, including Continental and American as well as British types, are next described, followed by chapters on steam traps, valves, feed pumps, indicators, etc., with special attention to filtering and softening of feed water and the superheating of steam. Under the section on fuel, mechanical stokers are described, with a discussion of the principles of combustion and the application of oil fuel. Several chapters are devoted to hydraulic tests and boiler evaporation trials, and to the causes and prevention of defects due to the wear and tear of boilers. The concluding chapter deals with the qualifications and duties of those engaged in the inspection of boilers, which, in Great Britain, is performed by staffs of engineers attached to boiler insuring and inspecting companies. The Chapter headings are: Materials Used in Construction; Strength of Boilers; Lancashire and Cornish Boilers and Their Modification; Vertical Boilers; Locomotive Boilers; Externally-Fired Boilers; Marine Boilers; Water-Tube Boilers; Heating Boilers and Steaming Vessels; Steam Stop Valves and Steam Dryers; Safety Valves; Feed, Blow-out and Scum Valves; Water Gauges, Alarms, Fusible Plugs; Pressure Gauges; Steam-Pipe Arrangements; Steam Traps; Reducing Valves; Feed Pumps and Injectors; Feed-Water Heaters and Evaporators; Filtering and Softening Feed Water; Superheating and Superheaters; Fuels and Combustion; Boiler Furnaces; Mechanical Stokers; Draught: Its Production and Regulation; Use of Oil Fuel; Non-Conducting Coverings for Steam Pipes; Corrosion in Boilers; Defects in Boilers; Hydraulic Tests; Boiler Evaporative Tests; Boiler Inspection. There is an index of fourteen pages.

* Unless otherwise specified, books in this list have been donated by the publisher.

LE DÉTROIT DE PANAMA.

Documents Relatifs à la Solution Parfaite du Problème de Panama (Détroit Libre, Large et Profond). Ces Documents Renferment des Détails sur la Solution très Imparfaite Adoptée par les Etats-Unis (Canal à Ecluses) et sur les Mauvais Résultats des trois premières Années de Travaux du Gouvernement Américain. Par Philippe Bunau-Varilla. Paper, 10 x 6½ in., illus., 305 pp. Paris, H. Dunod et E. Pinat, 1907. 10 francs.

The first part of this book is devoted to a comparison of the work accomplished by the old French Panama Canal Company from 1881 to 1888 with that done by the American Government from 1904 to 1907. This is followed by a report of the technical discussion of the subject before the Society of Arts, on January 23d, 1907, in London, England, together with the text of two letters addressed to President Roosevelt by the author. The second part comprises a statement by the author before the Board of Consulting Engineers as to the various problems connected with the construction of the Panama Canal. There is also contained reports of the Board of Consulting Engineers on the author's design for the canal; on the attitude of President Roosevelt before and after the report of the Board, etc. The author, it is stated, refutes the objections of the American engineers to a sea-level canal and concludes in favor of the original French project.

THE DESIGN AND CONSTRUCTION OF DAMS.

Including Masonry, Earth, Rock-Fill, Timber and Steel Structures. Also the Principal Types of Movable Dams. By Edward Wegmann, M. Am. Soc. C. E. Fifth Edition, Revised and Enlarged. Cloth, 12 x 9 in., illus., 13 + 421 pp. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1907. $6.00. (Donated by the Author.)

The first edition of this work was published in 1888 as a treatise on "The Design and Construction of Masonry Dams"; since that time four other editions, including the present one, have been issued. The subject-matter contained in this edition has been thoroughly revised and brought up to date. In Part I, which treats of the design and construction of masonry dams and which formed the original work, the latest theories of design are given. Descriptions of all the important dams built, or in the course of building, are given, and in the case of the New Croton Dam and a few others, the construction is described with considerable detail. Part II treats of fixed dams other than masonry, and Part III is devoted to descriptions of movable dams. The new matter added to these parts consists of descriptions of steel and concrete-steel dams, high earth dams, Stoney sluice-gates and rolling dams. The Appendix contains the Specifications for the New Croton Dam; twenty-five tables giving the dimensions and strength of various profile types, proofs of the principles discussed, and practical examples of the methods proposed for designing profiles, etc.; and a bibliography of the various types of dams described by the author. The book is illustrated by 120 figures in the text, by 34 half-tone plates and 100 folders, and there is an index of six pages. The Contents are: Part I, Design and Construction of Masonry Dams: Introduction; Distribution of Pressure in a Wall of Masonry; Theoretical Profiles; Various Applications of Equations (1) to (14); Practical Profiles; Construction; Spanish Dams; French Dams; Dams in Various Parts of Europe; Dams in Algiers; Dams in Egypt; Dams in Asia and Australasia; American Dams; Reinforced Concrete Dams. Part II, Earthen, Rock-Fill, Timber and Steel Dams: Earthen Dams; Dams Made by the Hydraulic Process; Rock-Fill Dams; Timber Dams; Steel Dams. Part III, Movable Dams: Frame Dams; Shutter Dams; Dams With Bear-Trap Gates; Stoney Roller Sluice-Gates, Rolling Dams, and Butterfly Dams; Recent Movable Dams; Appendix.

FOWLER'S MECHANICAL ENGINEER'S POCKET BOOK, 1908.

Edited by William H. Fowler. Tenth Annual Edition, Revised and Greatly Enlarged. Leather, 6 x 4 in., illus., 674 pp. Manchester, England, Scientific Publishing Co., 1907. 2 shillings 6 pence.

The contents of this edition, it is stated, have been thoroughly revised and greatly enlarged, the subject-matter having been rearranged in specific sections. The matter relating to building and building materials, which is now included in the special "Handbook for Architects and Builders," has been omitted from this publication. This is also true of that relating to machine tools and processes, which is to be published in a handbook specially devoted to workshop practice. Special attention has been given to the section relating to steam boilers and engines,

and much that is new has been added. There is also a new section dealing with pumps and pumping machinery, making the present volume exceed the previous editions by 100 pages. There is an index of twenty-eight pages.

RAILWAY CORPORATIONS AS PUBLIC SERVANTS.

By Henry S. Haines, M. Am. Soc. C. E. Cloth, 8 x 5½ in., 9 + 233 pp. New York, The Macmillan Company; London, Macmillan & Co., Ltd., 1907. $1.50. (Donated by the Author.)

The substance of this work was presented first as a course of lectures at the Boston University School of Law in May, 1907. It is stated in the preface that the work supplements, to some extent, a previous work on "Restricted Railway Legislation," as it describes the development of such legislation since the passage of the Act to Regulate Inter-state Commerce. The author discusses the question with regard to the amelioration of the relations existing between railway corporations and the public and considers "how they are affected as to their rights, powers, privileges, and obligations by reason of the duty which they owe to the community from being engaged in a public service." The Contents are: The Nature of a Public Service; The Public Service of a Railway; The Public Benefits Conferred by Railways; The Public Burdens Imposed by Railways; Recent Federal Legislation; The Results of Ineffectual Control of Railway Corporations; The Reasonableness of Railway Rates; The Standard of Railway Service; The Proper Regulation of Railway Service. There is an index of seven pages.

TABLES OF QUANTITIES FOR PRELIMINARY ESTIMATES.

By E. F. Hauch and P. D. Rice. Cloth, 7 x 4 in., illus., 3 + 92 pp. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1907. $1.25 net.

It has been the endeavor of the authors to make the scope of these tables broad enough to meet the requirements of the locating engineer and to present them in a form convenient for field use. Five, and in some cases, seven place logarithms have been used in the calculations, which, the authors state, have been carefully made. The formulas and methods of calculation are given so that tables for special cases may be readily prepared. To facilitate this, a table of second differences for prismoids and wedges, and of second and third differences for quarter cones, has been added. A few tables, other than those pertaining to earthwork, have also been included.

CLEAN WATER AND HOW TO GET IT.

By Allen Hazen, M. Am. Soc. C. E. Cloth, 8 x 5½ in., illus., 10 + 178 pp. New York, John Wiley & Sons, 1907. $1.50. (Donated by the Author.)

The subject-matter contained in this little book is stated by the author to be especially intended for mayors and aldermen and for those who have the power to bring about better conditions in regard to water-works and their management. The means now used by American cities to secure clean water are briefly discussed, with the application of these means to new problems. Closely allied subjects, such as matters of general policy, pressure and fire service, the sale of water, and the financial management of water-works, are also discussed. The Chapter headings are: Impounding Reservoir Supplies; Water Supplies from Small Lakes; Supplies from Great Lakes; Water Supplies from Rivers; Ground Water Supplies; On the Action of Water on Iron Pipes and the Effect Thereof on the Quality of the Water; Development of Water Purification in America; On the Nature of the Methods of Purifying Water; On the Application of the Methods of Water Purification, Arranged According to the Matters to be Removed by the Treatment; Storage of Filtered Water; On the Required Sizes of Filters and Other Parts of Water-Works; As to the Pressure Under Which Water is to be Delivered; On the Use and Measurement of Water; Some Financial Aspects; The Laying Out and Construction of Works; On the Financial Management of Publicly Owned Water Works. There is an index of four pages.

PRINCIPLES OF REINFORCED CONCRETE CONSTRUCTION.

By F. E. Turneaure, Assoc. M. Am. Soc. C. E., and E. R. Maurer. Cloth, 9 x 6 in., illus., 8 + 317 pp. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1907. $3.00.

The contents of this work are divided into two parts. The first part, Chapters I to VI, treats of the theory of the subject and presents the results of experiments.

Chapter I contains a brief historical sketch of reinforced concrete with a discussion of its uses and advantages as a form of construction. This is followed by a chapter on the properties of plain concrete and steel, which includes a discussion of the subjects of adhesion and relative contraction and expansion. The theoretical treatment of reinforced concrete is then considered, and all available tests on beams and columns are presented, together with the formulas and diagrams necessary in practice. The second part, Chapters VII to X, treats of the application of reinforced concrete to building construction, but only such illustrative material for actual design is given as is needed to make clear the principles involved, references being given in the text to works by other authors, which treat of the subject more fully. In the Chapter on Arches, the authors have given a complete general analysis of the solid arch rib, which, they believe, offers advantages over the usual graphical method. The Contents are: Introductory; Properties of the Material; General Theory; Tests of Beams and Columns; Working Stresses and General Constructive Details; Formulas, Diagrams and Tables; Building Construction; Arches; Retaining-Walls and Dams; Miscellaneous Structures. There is an index of three pages.

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Recherches sur l'Epuration Biologique et Chimique des Eaux d'Égout. Effectuées à l'Institut Pasteur de Lille et à la Station Expérimentale de la Madeleine. Par Le Dr. A. Calmette, avec la collaboration de MM. E. Rolants, F. Constant, E. Boullanger, L. Massol et M. le Professeur A. Buisine. 2 vol. Paris, Masson et Cie., 1905, '07.

Locomotive Compounding and Superheating. A Practical Text-Book for the Use of Railway and Locomotive Engineers, Students, and Draughtsmen. By J. F. Gairns. London, Charles Griffin & Company, Limited, 1907.

The Building Mechanics' Ready Reference. Stone and Brick Masons' Edition. By H. G. Richey. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1907.

Electricity in Mining. By Sydney F. Walker. New York, D. Van Nostrand Company, 1907.

The Marine Steam Turbine. A Practical Description of the Parsons Marine Turbine as Presently Constructed, Fitted, and Run, Including a Description of the Denny & Johnson Patent Torsion Meter for Measuring the Transmitted Shaft Horse-Power, and Containing Fifty Questions (with Solutions) on Elementary Turbine Design. By J. W. Sothern. Second Edition. New York, D. Van Nostrand Company; London, E. C. Whittaker & Co., 1906.

A Treatise on Hydraulics. By William Cawthorne Unwin. London, Adam and Charles Black, 1907.

Cement and Concrete. By Louis Carlton Sabin, M. Am. Soc. C. E. Second Edition, Revised and Enlarged. New York, McGraw Publishing Company, 1907.

How to Lay Out Suburban Home Grounds. By Herbert J. Kellaway. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1907.

Ordnance and Gunnery. A Text-Book Prepared for the Cadets of the United States Military Academy, West Point. By Ormond M. Lissak. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1907.

Die Maschinen-Elemente, ihre Berechnung und Konstruktion mit Rücksicht auf die Neueren Versuche. Von C. Bach. In Zwei Bänden. Erster Band: Text; Zweiter Band: Tafeln und Tabellen. Stuttgart, A. Kröner, 1903.

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DEATHS.

CLARK, JOHN HOWARD. Elected Member, November 4th, 1903; died October 13th, 1907.

HEQUEMBOURG, CHARLES EZRA. Elected Member, June 5th, 1901; died October 17th, 1907.

OBERNDORF, PAUL ERNEST. Elected Junior, February 5th, 1907; died October 13th, 1907.

WAINWRIGHT, JONATHAN. Elected Member, February 3d, 1892; died October 11th, 1907.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(October 8th to November 11th, 1907.)

NOTE.—*This list is published for the purpose of placing before the members of the Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(1) *Journal*, Assoc. Eng. Soc., 31 Milk St., Boston, Mass., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Blk., Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Anales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.

(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 803 Fulton Bldg., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne, England.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Industrial World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(70) *Engineering Review*, New York, City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.
(72) *Electric Railway Review*, Chicago, Ill., 10c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal, London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, Ill., 10c.
(77) *Journal*, Inst. Elec. Engrs., London, England.
(78) *Beton und Eisen*, Vienna, Austria.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie-Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Dinglers Polytechnisches Journal*, Berlin, Germany.
(83) *Progressive Age*, New York City, 15c.
(84) *Le Ciment*, Paris, France.
(85) *Proceedings*, Am. Ry. Eng. and M. of W. Assoc., Chicago, Ill.
(86) *Engineering-Contracting*, Chicago, Ill.
(87) *Roadmaster and Foreman*, Chicago, Ill., 10c.
(88) *Bulletin* of the International Ry. Congress Assoc., Brussels, Belgium.

LIST OF ARTICLES.

Bridge.

The Quebec Bridge Wreck.* (13) Oct. 10.
Ferro-Concrete Viaduct for the Cala Mineral Railway, Seville.* Mateo Clark. (11) Oct. 18.
The Manhattan Bridge Pedestal.* (14) Oct. 19.
The Erection of the Mocdna Creek Viaduct.* (14) Oct. 26.
Page Bascule Railroad Bridge over the Chicago River.* (18) Oct. 26.
Theodore Cooper on the Quebec Bridge and its Failure. (13) Oct. 31.
Bridge of Chicago & Northwestern, Pierre, S. D.* (40) Nov. 1.
The New Homberg Bridge.* (12) Nov. 1.
The Compressive Member.* Horace E. Horton. (18) Nov. 2.
The Lacing of Compression Members.* C. T. Morris, Assoc. M. Am. Soc. C. E. (13) Nov. 7.
The Reconstruction of the Anchor Piers of the Poughkeepsie Bridge.* (14) Nov. 9.
Ponts de Chemins de Fer à une Travée et à Voie Normale.* E. Pentecôte. (38) Oct.
Stabilité des Voutelettes Constituant le Platelage des Ponts Métalliques.* P. Caufourier. (33) Oct. 12.
Eisenbetonträger für grosse Spannweiten, System Vierendeel. (From a translation by Dr. F. Gebauer.) (78) Serial beginning Oct.
Der Einsturz der Brücke über den St. Lorenz-Strom in Quebec (Kanada).* (51) Oct. 16.

Electrical.

Modern Power Station and Electrical Construction.* W. A. Haller. (Paper read before the Louisiana Eng. Soc.) (1) Sept.
The Transmission Plant of the Niagara, Lockport and Ontario Power Company.* Ralph D. Mershon. (42) Sept.
Line Constants and Abnormal Voltages and Currents in High-Potential Transmissions.* Ernst J. Berg. (42) Sept.
The Grounded Neutral, with and without Series Resistance, in High-Tension Systems.* Paul M. Lincoln. (42) Sept.
Telephonic Transmission Measurements.* B. S. Cohen and G. M. Shepherd. (77) Sept.
The Present State of Direct Current Design as Influenced by Interpoles.* F. Handley Page and Fielder J. Hiss. (77) Sept.
Hot-Wire Wattmeters and Oscillographs.* J. T. Irwin. (77) Sept.

*Illustrated.

Electrical—(Continued).

A New Type of Induction Motor.* Louis J. Hunt. (77) Sept.
Further Notes on Electrical Conductivity; Stationary Contacts, Oiled and Dry.* William Browning. (77) Sept.
Electric "Valves."* E. W. Moss. (Abstract.) (77) Sept.
The Induction Motor.* Robert Rankin. (Abstract.) (77) Sept.
Constants of Cables and Magnetic Conductors.* Ernst J. Berg. (42) Oct.
The Secondary Current of the Induction Coil.* H. Clyde Snook. (3) Oct.
Long Distance Wireless Telephony.* R. A. Fessenden. (73) Oct. 4.
Test of a Combined Railway and Lighting Plant.* (17) Oct. 5.
The Comparative Development of Gas and Electricity as Illuminants.* J. C. Angus. (Paper read before the North of England Gas Mgrs. Assoc.) (66) Oct. 8.
On Transformer Indicator Diagrams.* T. R. Lyle. (Abstract of paper read before the Physical Soc.) (73) Oct. 11.
A Graphical Method of Determining the Voltage Drop in Power Distribution Systems.* (27) Oct. 11.
Hydro-Electric Power and Transmission Plant at West Buxton, Maine.* (27) Oct. 12.
Unbalanced Loads in Two-Phase to Three-Phase Transformation.* Bernh. F. Jakobsen. (27) Oct. 12.
Electrical Rolling Transporters.* (12) Oct. 18.
Excitation Characteristics of the Synchronous Motor.* A. S. Langsdorf. (27) Oct. 19.
A Pupin Cable in Deep Water.* L. Ramakers. (19) Oct. 19.
Combined Gas and Electricity Works at Ascot.* (73) Oct. 25; (26) Oct. 25.
Observations on the Electric Arc.* W. L. Upson. (73) Serial beginning Oct. 25.
The Supply of Electrical Energy for Industrial Purposes by the Manchester Corporation.* (27) Oct. 26.
The Thury Direct-Current Transmission System. D. Kos. (27) Oct. 26.
Public Light Service, Corporate and Municipal; a Study of the Cost of Electric Stations. Judson H. Boughton. (9) Nov.
Windmill Electricity Works in Denmark.* (26) Nov. 1.
Telephone Manufacturing at Liverpool.* (26) Nov. 1.
Remodeled Station of the Watertown Light & Power Company.* (27) Nov. 2.
Direct-Current Motors, their Action and Control.* F. B. Crocker and M. Arendt. (27) Serial beginning Nov. 2.
Wiring with Iron Conduit.* Louis J. Auerbacher. (27) Nov. 2.
Redondo Power Station of the Pacific Light & Power Company.* (72) Nov. 2.
Distribution and Breadth Coefficients of Alternators.* N. Stahl. (27) Nov. 9.
Les Commutateurs Téléphoniques Multiples à Batterie Centrale et à Signaux Lumineux.* A. Le Vergnier. (33) Sept. 28.
La Station Centrale d'Electricité de l'Exposition Internationale Maritime de Bordeaux.* Ch. Dantin. (33) Oct. 19.
L'Efficacité des Paratonnerres pour Cheminées d'Usines.* (33) Oct. 26.
Ein neues Verfahren zur Nutzbarmachung der Bremsleistung eines Prüffeldes für Kraftmaschinen. E. Kaufmann. (48) Oct. 12.
Der Einphasen-Wechselstrommotor. A. Linker. (82) Serial beginning Oct. 12.

Marine.

The Marine Type of Beam Engines.* R. C. Monteagle. (7) Sept.
The New Cable Steamer *Guardian*. (27) Oct. 18; (73) Oct. 18.
Grue de 150 Tonnes des Chantiers Navals John Brown à Clydebank (Angleterre).* (33) Oct. 12.

Mechanical.

Petrol Motor-Omnibuses. W. Worby Beaumont. (75) Mar.
Effects of Steam-Jacketing in Diminishing Condensation and Leakage. H. L. Callendar. (75) May.
Wastes from Lowell Gas Light Company's Yard. Arthur T. Safford. (Paper read before the Boston Soc. of Civ. Engrs.) (1) Sept.
The Equipment of Steam Turbine Generating Stations.* R. J. Kaula. (Abstract.) (77) Sept.
Gas-Power Central Station of the Duquesne Light Co., Pittsburg, Pa. Norman C. MacPherson. (42) Sept.
Bursting Strength of Malleable-Iron Pipe Fittings.* (64) Oct.
Combustion of Fuels. (64) Oct.
A New Development in Air Compressors.* Frederick A. Halsey. (64) Oct.
Diagram for Determining Pipe Sizes Necessary to Supply Direct Radiation at Varying Losses in Pressure and at Varying Distances.* Arthur McGonagle. (70) Oct.
The Combined Pressure and Vacuum System of Steam Heating.* George D. Hoffman. (Paper read before the Amer. Soc. of Heating and Ventilating Engrs.) (70) Oct.
Formula for Pipe Sizes in Hot Water Heating.* Oliver H. Schlemmer. (Paper read before the Amer. Soc. of Heating and Ventilating Engrs.) (70) Oct.

*Illustrated.

Mechanical—(Continued).

The Illuminating Power, in Ordinary and Incandescent Burners, of Coal Gas, Water Gas, and Mixtures of the Two Gases. Emile Sainte-Claire Deville. (Abridged tr. of paper read before the Inter. Photometric Comm.) (66) Serial beginning Oct. 1.

Parsons Type Steam Turbines.* Charles H. Naylor. (12) Oct. 4.

Thermal and Power Losses in Internal-Combustion Engines.* A. H. Burnand. (11) Serial beginning Oct. 4.

The Arrangement of Cage Guides for Modern Collieries.* J. S. Barnes. (22) Oct. 4.

Ferro-Alloys for Foundry Use. E. Houghton. (Paper read before the Brit. Foundrymen's Assoc.) (47) Oct. 5.

The *Coalite* Specifications. (66) Oct. 8.

The Comparative Value of Gas and Electricity as Illuminants.* J. C. Angus. (Paper read before the North of England Gas Mgrs. Assoc.) (66) Oct. 8.

Economy Tests of a 7 500-Kw. Westinghouse Parsons Steam Turbine.* J. R. Bibbins, Jun. M. Am. Soc. C. E. (13) Oct. 10; (14) Oct. 12; (64) Nov.; (18) Oct. 12; (27) Oct. 12; (17) Oct. 12; (47) Nov. 2.

The Arthur Koppel Company's New Works.* (20) Oct. 10.

Liquid Fuel for Internal-Combustion Engines. R. W. A. Brewer, A. M. Inst. C. E. (Paper read before the Soc. of Engrs.) (47) Oct. 12.

Complete New Gas-Works for Auckland, New Zealand.* Chenery Suggate, Assoc. M. Inst. C. E. (66) Serial beginning Oct. 15.

New Methods and Plant at Cardiff, a Large Installation of West's Stoking Machinery and Coke-Handling Plant.* (66) Oct. 15.

Sulphur and Oil Gas. P. W. Prutzman. (Paper read before the Pacific Coast Gas Assoc.) (83) Oct. 15.

Comparative Economics in Operating Small Motors by Gas, Gasoline and Electricity. L. H. Newbert. (Paper read before the Pacific Coast Gas Assoc.) (83) Oct. 15.

Locomotive Coals.* A. Jacobsen. (12) Oct. 18.

Large German Gas Engines.* (73) Serial beginning Oct. 18.

Some Practical Points in Steam Turbine Construction; with Particular Reference to the Parsons Type.* St. John Chilton. (Paper read before the Amer. St. and Interurban Ry. Assoc.) (17) Oct. 19.

Heating System of the St. Francis Home, Detroit, Mich.* (14) Oct. 19.

Melting Iron for Foundry Purposes.* E. L. Rhead. (47) Serial beginning Oct. 19.

Contact Method of Gas Engine Ignition.* E. J. Edwards. (27) Oct. 19.

City of Bahia Blanca (Argentine Republic) New Gas-Works.* (66) Oct. 22.

Maintenance of Mains in a Mining District.* W. C. Jones. (Paper read before the Midland Assoc. of Gas Mgrs.) (66) Oct. 22.

Heating and Ventilating the Commercial National Bank Building, Chicago.* (14) Serial beginning Oct. 26.

Practical Experience with Exhaust-Steam Turbines.* Alfred Gradenwitz. (9) Nov.

Steam Production from the Cheaper Grades of Anthracite. William D. Ennis. (9) Nov.

Cost of Power. C. T. Wilkinson. (64) Nov.

The Thomas Steam Calorimeter.* Carl C. Thomas. (64) Nov.

Boiler Rules. (Report of the Board of Boiler Rules, Mass.) (64) Nov.

The Parker Steam Generator.* (Report of the Comm. on Science and Arts, on the invention of John C. Parker.) (3) Nov.

The First Steam Superheaters.* Charles R. King. (15) Nov. 1.

Test of Large Turbo-Generators in the United States.* (12) Serial beginning Nov. 1.

A Modern Retail Coal Pocket.* Charles J. Steffens. (14) Nov. 2.

Boiler Blow-Off Connections.* R. T. Strohm. (27) Nov. 2.

Tests of Gasoline Engines using Alcohol. (14) Nov. 2.

Steam-Driven Transmission Stations of the Società Lombarda, of Milan, Italy.* (27) Nov. 9.

Sur l'Effet de la Compression de la Vapeur dans l'Espace Nuisible des Machines à Vapeur.* J. Boulvin. (31) Pt. 2.

Fiacre Automobile à Transmission par Plateaux de Friction.* A. Le Vergnier. (33) Oct. 19.

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PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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MUNICIPAL REFUSE DISPOSAL: AN INVESTIGATION.

By J. T. Fetherston, Assoc. M. Am. Soc. C. E.

To be Presented December 18th, 1907.

For a number of years the disposal of municipal refuse in the Borough of Richmond, New York City, has been the subject of much concern to responsible authorities. The first attempt to deal systematically with solid organic waste was made in 1895, when the former Village of New Brighton erected a Brownlee crematory, and collected garbage separated from other refuse. In 1898, the general Department of Street Cleaning introduced the separation system throughout the Borough of Richmond, and ashes, rubbish, and street sweepings were used for filling sunken lots, while garbage within economical hauling distance of a Dixon crematory (erected in 1899) was destroyed, the remainder being mixed with ashes, etc., and dumped on isolated properties. In 1902, when the city charter was amended, the collection and disposal of refuse, with other street-cleaning work, came under the control of the Borough President.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

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FETHERSTON ON
REFUSE DESTRUCTION.

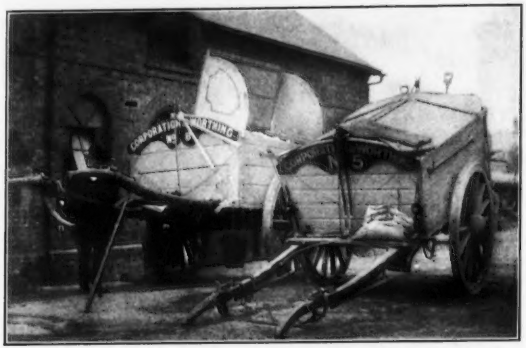


FIG. 1.—COVERED REFUSE COLLECTION CARTS AT WORTHING.

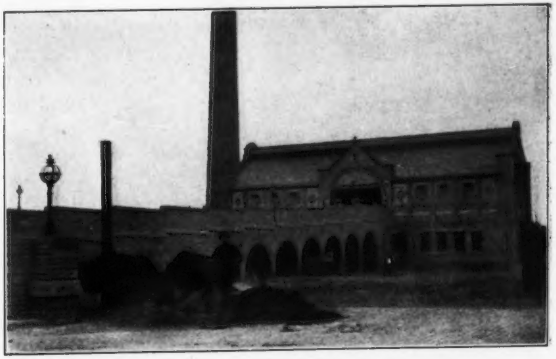


FIG. 3.—SALTLEY DESTRUCTOR, BIRMINGHAM.



FIG. 2.—TIPPING REFUSE INTO STORAGE HOPPER AT WATFORD.

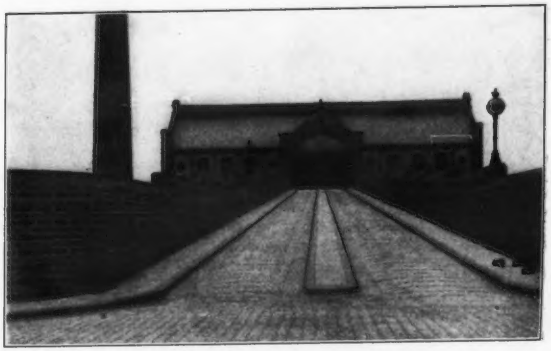


FIG. 4.—LOOKING UP RUNWAY AT SALTLEY.

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The writer was placed in charge of the Bureau of Street Cleaning in 1904, and found the conditions regarding refuse disposal as follows:

1.—The separation of garbage from ashes and rubbish was imperfect. Short-haul ash dumps were sources of complaint. Land for the disposal of refuse was becoming scarce. The cremation of garbage as practiced was costly and unsatisfactory. Little trouble was experienced in the use of street sweepings for filling sunken lots, as macadam roads adjoined paved streets and the sweepings contained relatively small percentages of organic matter.

2.—The loss of short-haul dumping grounds had progressed to the point where provision for power transportation to waste lands, or some other means of final disposition of household refuse, became necessary. Efforts to obtain a reasonable rate of transportation by street railway to outlying properties failed. Examination, tests, and studies of existing garbage crematories offered no hopes of satisfying permanently the requirements of economical and sanitary final disposition. The location, population, and topography of the built-up districts under consideration rendered any means of disposal other than incineration inadvisable.

After a study of available publications on the subject, it became evident that the British method of destroying mixed refuse would solve the problem if the local refuse contained enough combustible material to consume all noxious wastes without nuisance, and provided that a reasonable degree of economy in operation could be attained.

From various books, reports, etc., the following general abstract of English practice in destroying mixed refuse was compiled:

A.—Refuse destructors are centrally located in populous districts, and are reported to be operated without nuisance.

B.—Average British household refuse consists of one-third combustible, one-third water and one-third mineral matter, by weight (Watson). This material is burned in brick furnaces by the aid of forced draft without the use of additional fuel. High temperatures are attained, and the waste gases are brought into contact with steam boilers, thus producing power which is utilized for various purposes. Each pound of average unscreened refuse will evaporate its own weight of water.

C.—The residue consists of clinker, fine ash, and dust, amounting to about one-third, by weight, of the original material. Clinker is

Photographed June 15th, 1906.

Fig. 4.—Near View of Refuse at Fox Hills, Borough of Richmond, N. Y., June 27th, 1906.

TABLE 1.—Composition of Refuse from Different Cities, Classified Approximately.

Description.	Fine ash, dust and dirt. Percentage.	Clinker. Percentage.	Glass, metal, etc. Percentage.	Coal, coke, breeze, and cinder. Percentage.	Garbage. Percentage.	Rubbish. Percentage.	Paper, straw and fibrous material, vegetables, bones, and offal. Percentage.	Authority.
Average Ash-bin Refuse, England	32.00	.....	3.00	51.00	.....	.....	14.00	Hutton.
London Refuse	52.60	.....	3.575	28.95	.....	.....	14.875	Codrington.
London Ash-bin Refuse	19.51	.....	2.98	64.53	.....	.....	12 98	Russell.
Torquay, Eng., Dec. and Jan., Refuse	25.42	.....	3.17	6.51	52.42	12.29	.....	Goodrich { "Disposal of Towns Refuse" p. 139.
Torquay, Eng., June Refuse	48.05	.....	5.50	28.92	13.32	4.21	.....	" " p. 141.
Berlin, Germany:								
April Refuse	57.12	1.58	7.02	1.33	29.53	3.42	.....	Bohm and Grohn (Hering).
August Refuse	43.19	1.18	9.28	1.53	36.62	8.20	.....	" " "
New York	52.30	.....	0.46	28.17	12.20	6.87	.....	Craven (Hering).

Chemical Analysis of Berlin Refuse, by Bohm and Grohn (Hering).

Description of material.	Hygroscopic water. Percentage.	Combined water and carbonic acid. Percentage.	Combustible organic matter. Percentage.	Incombustible. Percentage.
Sifted	10.91	2.54	13.27	73.28
Coarse	26.55	9.53	10.20	53.72
Unsifted (computed.)	17.62	5.54	11.94	54.90

Chemical Analysis of Refuse from Kings Norton (near Birmingham), Eng.

	Percentage.
Carbon	36.80
Hydrogen	0.29
Nitrogen	0.29
Sulphur	0.19
Oxygen	7.30
Ash	41.70
Moisture	12.12
Total	98.69

Theoretical calorific value of this refuse given as 4 500 B. t. u. (From Specification, p. 26.)

Calorific Values of English Refuse Components with Average Percentage of Moisture (Dawson).

Coal	9 334 B. t. u.
Coke	8 000 "
Bones and Offal	5 334 "
Breeze and Cinder	4 000 "
Rags	3 334 "
Paper, straw, fibrous material, and vegetable refuse	2 534 "

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FIG. 1.—MIXED-REFUSE DUMP AT FOX HILLS, BOROUGH OF RICHMOND, N. Y., JUNE 27TH, 1906.



FIG. 2.—AN OLD REFUSE HEAP AT WORTHING, ENGLAND, PHOTOGRAPHED JUNE 15TH, 1906.



FIG. 3.—REFUSE ON STORAGE, LLANDUDNO, WALES, MAY 19TH, 1906.



FIG. 4.—NEAR VIEW OF REFUSE AT FOX HILLS, BOROUGH OF RICHMOND, N. Y., JUNE 27TH, 1906.

useful as an aggregate in making concrete slabs, bricks, etc. If not utilized, the residue makes acceptable filling.

D.—The cost of labor and supervision per ton of refuse destroyed amounts to about 30 cents in England. The economy of the process depends to a great extent upon the utilization of the steam generated.

Up to this time (1904), all available information concerning the composition of refuse from different localities was summarized as shown in Table 1. These figures were so meager and unsatisfactory for the case in hand that only two courses were open: namely, build a destructor, with the risk of failure; or make a thorough examination of the whole question, to determine the best means of disposal should mixed refuse destruction prove unsatisfactory.

The object of this paper is to present the results of an investigation covering:

First, the quantity, composition, seasonal variations, and calorific power of local household refuse, with a series of practical tests in burning mixed wastes; and second, some data, observations, and deductions concerning a number of mixed-refuse destructors visited by the writer.

Part I.

Richmond Borough (Staten Island) has an estimated population of about 80 000, and an area of 57.2 sq. miles. It is divided into three refuse collection districts, two of which, containing the bulk of the population, are served by municipal carts, while the third, comprising the country or sparsely-settled sections, is served by hired carts.

One of the refuse collection divisions, known as the West New Brighton District, was selected as a representative portion of the borough from which to obtain the desired information concerning the problem of disposal. By actual count, there were 4 321 houses in this district, containing about 25 900 people, 90% of whom contribute wastes for removal by city carts.

The plan adopted contemplated obtaining data concerning:

I.—The quantity of refuse contributed per 1 000 inhabitants per day, by volume and by weight;

II.—The seasonal variations in quantity of refuse, by volume and by weight;

III.—The components of refuse, and their seasonal variations;

IV.—The calorific power of refuse, and its seasonal variations; also the seasonal variations in the calorific power of the components of refuse;

V.—The practical incineration of mixed refuse;

VI.—The probable temperature of the gases resulting from the destruction of refuse, and the boiler-power obtainable with seasonal variations.

Definitions.—Household refuse means practically all materials collected by municipal carts from private residences, stores, and small factories. Night-soil, dead animals, and trade refuse, such as building refuse and large manufacturing wastes, are not included.

Ashes consist mainly of the residue from domestic fires, from schools, churches, etc., and include other inorganic material, such as glass, crockery, metallic substances, dust, bricks, stones, earthenware, etc.

Garbage is composed of organic materials—vegetable and animal matter—with water and grease.

Rubbish consists of light combustible articles, such as paper, rags, excelsior, straw, wood, leather, rubber, etc.

I.—Quantity of Refuse.—Table 2 records in convenient form the quantities of different classes of household refuse as collected in the West New Brighton District.

The volumes of the different classes of refuse were obtained by careful records of cart loads. The adopted unit weights were the average results of numerous determinations. Table 2 shows that the average quantity of household refuse collected amounted to about 3.7 cu. yd. or 1.6 tons per 1 000 inhabitants per day during the period considered.

II.—Seasonal Variations in Quantity of Refuse.—Referring to Table 2, it will be noted that the volume of the total collection for any month differs slightly (from 8% above to 12% below the average), while the weight varies from 23% above the average in winter and spring to 30% below the average in summer or fall. The two classes of refuse have opposite variations by weight, "ashes and rubbish" being high in winter and low in summer, while "garbage" is low in winter and high in summer. Unseasonable weather and abnormal variations in the fuel and food supply will cause further differences in the amounts of "ashes," "rubbish," and "garbage."

TABLE 2.—Household Refuse as Collected, West New Brighton District.

Month.	Ashes and Rubbish.						Garbage.						Total Collection.			
	Volume.			Weight.			Volume.			Weight.			Volume.		Weight.	
	Cubic yards.	Percentage of 12 months' collection.	Percentage of total monthly collection.	Tons.	Percentage of 12 months' collection.	Percentage of total monthly collection.	Cubic yards.	Percentage of 12 months' collection.	Percentage of total monthly collection.	Tons.	Percentage of 12 months' collection.	Percentage of total monthly collection.	Cubic yards.	Percentage of 12 months' collection.	Tons.	Percentage of 12 months' collection.
1906.																
January	2 014	9.3	83.1	962.9	10.6	83.5	409	5.7	16.9	190.6	5.7	16.5	2 423	8.4	1 153.5	9.3
February	1 852	8.6	87.5	871.5	9.6	87.6	265	3.7	12.5	123.5	3.7	12.4	2 117	7.4	995.0	8.0
March	2 139	10.2	85.5	1 072.7	11.8	86.0	373	5.2	14.5	173.8	5.2	14.0	2 572	9.0	1 246.5	10.1
April	1 972	9.1	78.3	973.8	10.7	79.3	545	7.7	21.7	254.0	7.7	20.7	2 517	8.8	1 227.8	9.9
May	1 857	8.6	76.4	890.4	10.9	78.7	574	8.1	23.6	267.5	8.1	21.3	2 431	8.5	1 257.9	10.2
June	1 725	8.0	73.7	734.0	8.1	71.9	617	8.7	26.3	287.5	8.7	28.1	2 342	8.2	1 021.5	8.2
July	1 516	7.0	69.9	426.0	4.7	58.3	653	9.2	30.1	304.3	9.2	41.7	2 169	7 5	730.3	5.9
August	1 661	7.7	68.8	417.4	4.6	54.3	753	10.6	31.2	350.9	10.6	45.7	2 414	8.4	768.3	6.2
September	1 677	7.7	65.3	429.1	4.7	50.9	889	12.5	34.7	414.3	12.5	49.1	2 566	8.9	843.4	6.8
1905.																
October	1 567	7.2	66.1	564.7	6.2	60.1	808	11.3	33.9	374.2	11.3	39.9	2 370	8.2	938.9	7.6
November	1 678	7.8	72.0	759.8	8.4	71.4	652	9.2	28.0	308.8	9.2	28.6	2 330	8.1	1 063.6	8.6
December	1 894	8.8	76.7	877.5	9.7	76.6	574	8.1	23.3	267.5	8.1	23.4	2 468	8.6	1 145.0	9.2
Totals	21 612	100		9 079.8	100		7 107	100		3 311.9	100		28 719	100	12 391.7	100
Percentage of total collection		75.2			73.3			24.8			26.7			100		100
Average amount per 1 000 inhabitants per day		2.77			1.164			0.91			0.425			3.68		1.589

Note.—One ton = 2 000 lb. { Daily collection of refuse, except Sundays and holidays.
{ Average weights per cubic yard: ashes and rubbish = 0.42 ton; garbage = 0.466 ton.

III.—Components of Refuse and Their Seasonal Variations.—Mechanical analyses, by weight, of the two classes of refuse shown in Table 2 were made during 1904, 1905, and 1906, as often as other work permitted. Cart loads of "ashes and rubbish," amounting to

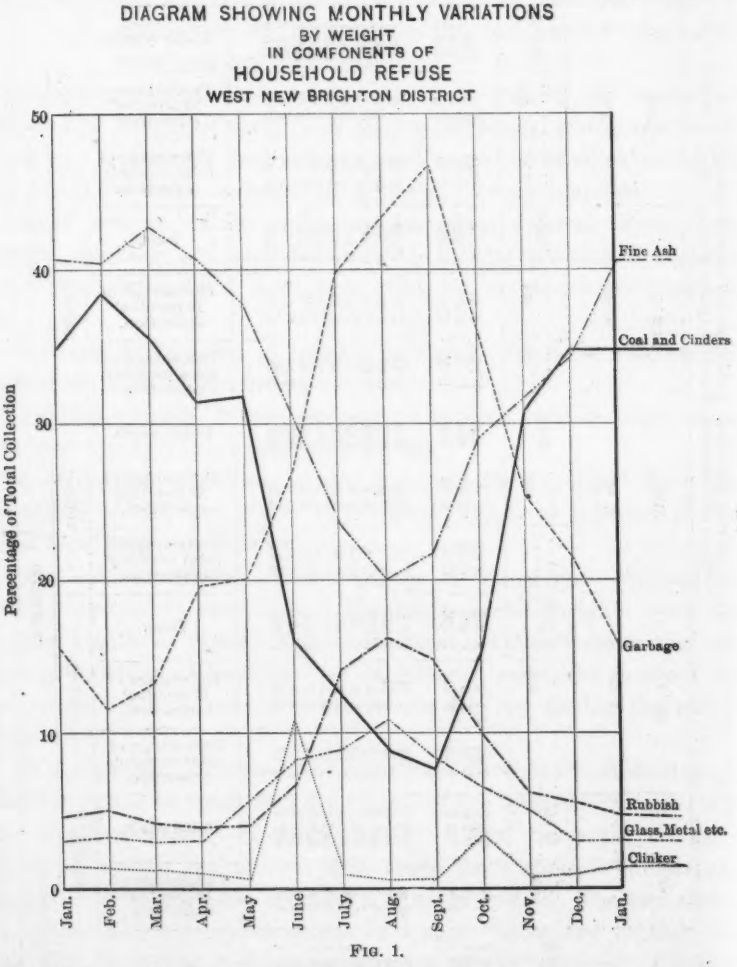


FIG. 1.

107 907 lb., from different portions of the district, were analyzed, and 562 samples of garbage, amounting to 28 101 lb., were separated into components. A $\frac{3}{8}$-in. mesh screen was used to divide the "ashes and rubbish," the material passing through the screen being termed

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FIG. 1.—BERMONDSEY DESTRUCTOR IN REAR OF TOWN HALL.



FIG. 2.—ANOTHER VIEW, SHOWING LOCATION, BERMONDSEY DESTRUCTOR.

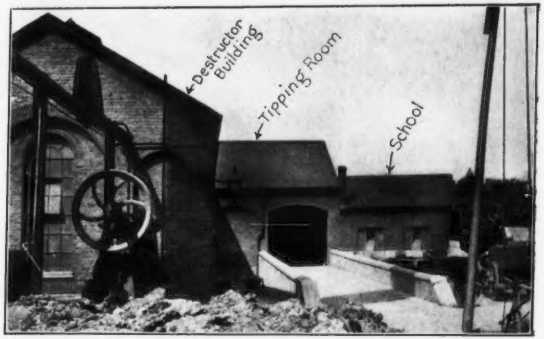


FIG. 3.—SHEERNESS DESTRUCTOR. A SCHOOL HOUSE IS ONLY 8 FT. AWAY FROM THE REFUSE STORAGE ROOM.



FIG. 4.—VIEW FROM WATER TOWER AT SHEERNESS, SHOWING SURROUNDINGS OF DESTRUCTOR.

"fine ash," while "coal and cinders" were the materials rejected by the screen and not otherwise classified as "rubbish," "clinker," "glass, metal, etc.," separated by hand-picking. Small samples (averaging 50 lb. each) of "garbage" were separated into components by hand. The average results of the monthly determinations were used in connection with the figures in Table 2 to compute Table 3 which gives the results of the mechanical analyses. The graphic diagram, Fig. 1, brings out clearly the relative variations in the components of refuse from this district, and, as "garbage" is the primary cause of nuisance, it indicates that September will be the critical month when destroying mixed household wastes. February represents the opposite extreme of low "garbage" and high "coal and cinders." The large percentage of "fine ash" in winter suggests the advisability of removing this material, though the decision in this respect will depend upon practical experience in dealing with the refuse. As "garbage" carries nearly all the moisture in mixed refuse, a series of forty-one evaporative tests was made in order to determine its water content. Samples averaging 39 lb. were dried in a special water-jacketed evaporation pan, with the results indicated in Table 4.

TABLE 3.—COMPOSITION OF HOUSEHOLD REFUSE BY WEIGHT.

Month.	From Table 2.		From Mechanical Analysis.							
	Ashes and rubbish. Percentage.	Garbage. Percentage.	Fine ash. Percentage.	Clinker. Percentage.	Glass, metal, etc Percentage.	Coal and cinders. Percentage.	Garbage.			Rubbish. Percentage.
							Vegetable. Percentage.	Animal. Percentage.	Free water. Percentage.	
1906.										
January	83.5	16.5	40.5	1.4	3.1	34.7	14.3	0.6	0.7	4.7
February	87.6	12.4	40.3	1.3	3.4	38.3	10.9	0.4	0.3	5.1
March	86.0	14.0	42.6	1.2	3.1	35.5	12.2	0.5	0.6	4.3
April	79.3	20.7	40.8	1.0	3.2	31.5	17.9	0.8	0.8	4.0
May	78.7	21.3	37.7	0.6	5.7	31.8	18.7	0.7	0.7	4.1
June	71.9	28.1	30.7	11.1	8.4	16.2	24.4	1.0	1.4	6.8
July	58.3	41.7	23.8	0.8	9.0	12.6	36.3	1.6	1.7	14.2
August	54.3	45.7	20.0	0.5	10.9	9.0	39.7	1.7	3.0	16.2
September	50.5	49.1	21.7	0.6	8.5	7.7	42.5	1.9	2.2	14.9
1905.										
October	60.1	39.9	29.0	3.5	6.6	15.2	30.9	3.1	1.5	10.2
November	71.4	28.6	31.8	0.7	5.2	30.8	22.6	1.8	1.0	6.1
December	76.6	23.4	34.4	0.9	3.1	34.6	19.6	1.1	0.8	5.5
Averages	73.3	26.7	34.7	1.8	4.8	26.7	22.6	1.2	1.1	7.1

TABLE 4.—Evaporative Tests of Moisture in Garbage.

Date.	Weight of original sample, in pounds.	Weight of dried sample, in pounds.	Water evaporated, in pounds.	Water in original sample. Percentage	Hours drying.	Average water by months. Percentage.
Jan. 4, '06	46	10.09	35.91	78.2	88	75.9
Jan. 17, '06	50	13	37	74.0	104	
Feb. 8, '06	50	13.65	36.35	72.7	136	72.2
Feb. 26, '06	47	13.31	33.69	71.7	144	
March 23, '05	50	16	34	68.0	70	68.6
March 19, '06	49	15.09	33.91	69.2	96	
April 1, '05	40	12.5	27.5	68.7	70	69.6
April 7, '05	40	11	29	72.5	80	
April 2, '06	42	13.31	28.69	68.3	128	
April 20, '06	50	15.5	34.50	69.0	128	
May 17, '05	40	12	28	70.0	70	70.7
May 25, '05	39	12	27	69.2	60	
May 9, '06	47	13.5	33.5	71.3	104	
May 24, '06	50	14.0	36.0	72.0	130	
June 19, '05	39	8	31	79.4	60	70.6
June 9, '06	35	13.5	21.5	61.4	88	
June 25, '06	35	10.5	24.5	70.0	112	
July 2, '05	30	9.0	21	70.0	60	71.0
July 22, '05	39	11	28	71.8	70	
July 31, '05	39	9	30	76.9	60	
July 13, '06	46	13.5	32.5	70.6	104	
July 31, '06	36	12.5	23.5	65.3	80	
August 6, '05	39	9	30	76.9	60	74.7
August 11, '05	38	11	27	71.0	60	
August 27, '05	44	11	33	75.0	60	
August 14, '06	45	11	34	75.5	112	
Sept. 4, '05	38	10	28	73.6	70	73.1
Sept. 18, '05	45	13	32	71.1	50	
Sept. 20, '04	38	9.5	28.5	75.0	90	
Sept. 8, '06	45	11.5	33.5	74.4	60	
Sept. 17, '06	44	12.5	31.5	71.6	100	
Oct. 3, '05	26	8	18	69.2	50	67.4
Oct. 17, '05	33	12	21	63.6	50	
Oct. 26, '05	29	9	20	69.0	50	
Oct. 20, '04	47	15	32	68.1	100	
Nov. 6, '05	44	13	31	70.5	88	69.2
Nov. 16, '05	37	10.92	26.08	70.5	64	
Nov. 25, '05	36.5	12.31	24.19	66.3	104	
Dec. 11, '05	45	9.84	35.16	78.1	160	.....
Average per cent. of water..	.....	.....	.....	71.4	.....	.....

PUT IN OPERATION.

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FIG. 1.—VIEW SHOWING LOCATION OF DESTRUCTOR AT WREXHAM.

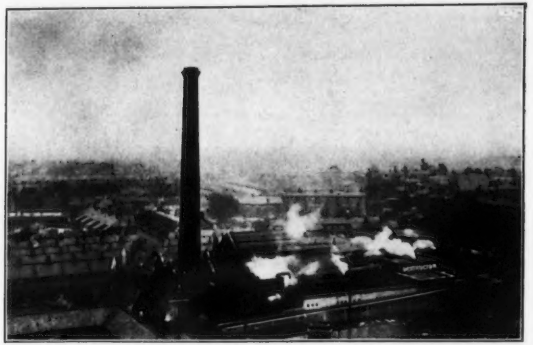


FIG. 3.—RATHMINES DESTRUCTOR, IRELAND. VIEW OF PLANT AND SURROUNDINGS FROM CLOCK TOWER OF TOWN HALL.



FIG. 2.—VIEW FROM WATER TOWER AT WREXHAM, SHOWING HOUSES NEAR DESTRUCTOR BUILDING.

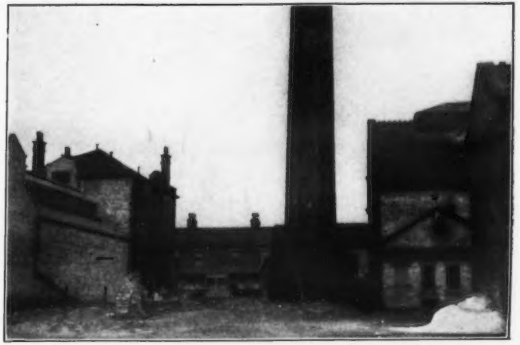


FIG. 4.—MOSS SIDE DESTRUCTOR, MANCHESTER. HOUSES IN BACKGROUND WERE ERECTED AFTER DESTRUCTOR WAS PUT IN OPERATION.

IV.—Calorific Power of Refuse—Seasonal Variations.—Mixed refuse seemed to be an unpromising material for reduction to representative samples suitable for test in a calorimeter, but separate determinations of the components of refuse in conjunction with the mechanical analyses might be expected to serve the purpose of computing the calorific power of the refuse, within reasonable limits, for practical purposes.

Table 5 summarizes the principal features of a set of preliminary tests made at the Lederle Laboratories. The calorific determinations gave rather better results than might have been expected under the conditions of sampling then prevailing. An insufficient number of trials was made to show any seasonal variations in the heat values of the materials. Mixed refuse tests proved unsatisfactory, as might have been expected. A composite sample (No. 7488), by actual test and by computation, showed practical agreement, thus checking the assumption that the total calorific power of the refuse would equal the sum of the heat values of its constituents.

In February, 1907, there became available a very comprehensive series of calorific determinations, made during 1905 and 1906 at the laboratory of the Commissioners of Accounts, under the direction of Mr. Otto H. Klein, Chief Engineer, by B. F. Welton, Assoc. M. Am. Soc. C. E. Large amounts of the several components of refuse, from the mechanical analyses for each month, were reduced by quartering, moisture was evaporated from "garbage," and the different materials were roughly pulverized to representative samples at the West New Brighton crematory. Further preparation of samples for test in a Mahler bomb calorimeter was made at the laboratory. The method of procedure in these determinations differed from that of the preliminary determinations in the case of "rubbish," where the paper content was not pulped before being pulverized, also with "fine ash" and "clinker," which were burned with naphthaline to effect complete oxidation of the relatively small percentage of combustible matter.

The results of the various calorific determinations and proximate analyses by Mr. Welton, with the average seasonal variations of the different components, are shown in Table 6.

In this summary "coal and cinders" has a lower value in winter than during other seasons of the year, probably owing to the more complete combustion of fuel in cold weather; "garbage" shows no

4 368*D*	Rubbish.	February.	6 940	0.75	17.03	82.22	8 441	Original bulk sample reduced by quartering, paper portion pulped, coarsely ground with other rubbish, quartered, dried, pulverized, and again quartered down to test sample. Test results refer to original sample.
4 369*B*	"	February.	12 634	0.00	5.66	94.34	13 392	
4 665	"	March.	7 251	2.78	12.58	84.64	8 567	
6 280	"	May.	7 943	3.70	13.21	83.09	9 560	
7 357	"	July.	7 781	1.03	21.39	77.58	10 029	
7 358	"	July.	8 404	0.80	11.93	87.27	9 630	
7 440	"	August.	8 107	3.77	8.15	88.08	9 204	
	Average		8 437	1.83	12.85	85.32	9 889	
4 368*A*	Fine ash.	February.	0 000	3.03	80.45	16.52	.....	Same procedure as in "coal and cinders."
4 667	" "	February.	0 000	0.56	83.67	15.77	....	
	Average		.....	1.79	82.06	16.14	.....	
4 368*C*	Clinker.	February.	0 000	1.14	89.25	9.61	.....	Same procedure as in "coal and cinders."
4 666	"	February.	0 000	0.61	90.34	9.05	.....	
	Average		.....	0.87	89.80	9.33	.....	
4 668	Mixed refuse.	February.	3 903	0.00	46.89	53.11	7 349	Procedure as with components noted above. Total moisture not determined.
5 373	" "	April.	6 084	3.42	38.61	57.97	10 495	
6 918	" "	June.	5 700	0.31	58.95	40.74	13 991	
	Average		5 229	1.24	48.15	50.61	10 332	
7 488	Composite sample. Computed from separate tests.	See Laboratory Nos. 7 439, 7 440, 7 441.	8 254 8 452	1.18 2.26	21.35 21.14	77.47 76.58	10 654 11 037	Composed of: 53.4% Garbage, test No. 7 439. 19.6% Rubbish, " " 7 440. 27.0% Coal and cinders, test No. 7 441.

TABLE 5.—CALORIMETER TESTS. (PRELIMINARY SERIES.)

Laboratory No.	Material.	From collections in:	Test Results. Calorific power in B. t. u.	Percentage of water.	Percentage of ash.	Percentage of combustible.	Calorific power of combustibles in B. t. u. Computed.	Notes.
		1905.						
4 368*A*	Coal and cinders.	February.	4 230	1.02	61.17	37.81	11 187	
4 663	" " "	February.	3 280	1.63	52.14	46.23	7 095	
5 074*A*	" " "	March.	4 590	1.55	59.11	39.34	11 668	Original bulk sample reduced by quartering, pulverized, and again quartered down to test sample. Test results refer to original sample.
5 425*B*	" " "	April.	4 837	1.54	55.54	42.92	11 269	
6 282	" " "	May.	2 108	2.74	68.69	28.57	7 378	
7 359	" " "	July.	7 710	0.99	39.38	59.63	12 980	
7 441	" " "	August.	7 554	2.01	42.42	55.57	13 594	
	Average	.....	4 901	1.64	54.06	44.29	11 066	
4 369*A*	Garbage.	February.	5 320	4.47	32.44	63.09	8 432	
4 664	"	February.	9 447	2.68	11.92	85.40	11 062	
5 074*B*	"	March.	7 874	0.00	12.19	87.81	8 967	Original bulk sample reduced by quartering, moisture evaporated, pulverized and again quartered down to test sample. Test results refer to practically dry garbage. For moisture in original material, see Table 4.
5 425*A*	"	April.	8 965	0.00	22.48	77.52	11 565	
6 281	"	May.	8 186	1.63	18.26	80.11	10 218	
7 356	"	July.	8 878	0.00	13.04	86.96	10 209	
7 439	"	August.	9 034	1.84	15.16	83.00	10 884	
	Average	.....	8 243	1.52	17.93	80.55	10 233	

TABLE 6.—CALORIMETER TESTS AND

COAL AND CINDERS. (26 TESTS.)

Laboratory No.	Calorific Values.			From Collections Made:		Proximate Analyses.			
	Per pound. original sample. B. t. u.	Per pound, dry sample. B. t. u.	Per pound. combustible. B. t. u.	Season.	Month and year.	Moisture. Percentage.	Volatile matter. Percentage.	Fixed carbon. Percentage.	Ash. Percentage.
921*b*	9 360	9 470	14 750	Spring ...	Early March, 1906	1.14	4.02	59.44	35.40
922*b*	8 180	8 260	14 290		Late " 1906	0.97	2.83	54.40	41.80
928*b*	8 630	8 765	15 010		Early April, 1906	1.52	4.36	53.14	40.98
929*b*	9 360	9 505	14 270		Late " 1906	1.50	3.40	62.20	32.90
936*b*	7 840	7 932	14 340		Early May, 1906	1.08	2.04	52.66	44.22
946*b*	9 645	9 850	14 400		Late " 1906	2.02	4.88	62.13	30.97
	8 836	8 957	14 504	Average, spring.....		1.37	3.59	57.33	37.71
952*b*	9 497	9 590	15 270	Summer.	Early June, 1906	2.03	4.90	56.60	36.47
971*b*	9 930	10 110	13 850		Late " 1906	1.78	5.09	66.67	26.46
833*b*	7 865	8 013	14 500		July, 1905	1.90	14.70	39.60	43.80
975*b*	7 150	7 250	14 020		Early " 1906	1.37	2.88	48.13	47.62
976*b*	9 740	9 967	14 050		Late " 1906	2.23	2.91	66.43	28.43
994*b*	9 520	9 770	14 450		Early August, 1906	2.06	6.98	59.10	31.86
995*b*	7 080	7 135	13 860		Late " 1906	0.75	3.91	47.16	48.18
	8 690	8 843	14 312	Average, summer		1.73	5.91	54.81	37.55
858*b*	8 561	8 813	12 800	Autumn.	September, 1905	2.24	7.78	59.16	30.82
998*b*	10 865	11 135	14 420		Early Sept., 1906	2.32	4.02	71.38	22.28
1 011*b*	10 585	10 840	14 980		Late " 1906	2.28	4.05	66.57	27.10
862*b*	7 805	7 920	13 580		Early Oct., 1905	1.42	1.12	56.36	41.10
875*b*	8 445	8 540	15 065		Late " 1905	1.04	2.02	54.04	42.90
882*b*	8 490	8 580	15 010		Early Nov., 1905	1.03	1.85	54.73	42.39
887*b*	7 378	7 440	15 225		Late " 1905	0.82	2.13	46.33	50.72
	8 876	9 020	14 397	Average, autumn.....		1.59	3.28	58.37	36.76
894*b*	7 270	7 320	14 460	Winter...	Early Dec., 1905	0.62	2.21	48.07	49.10
895*b*	8 210	8 265	13 810		Late " 1905	0.65	1.59	57.84	39.92
899*b*	6 940	6 980	13 450		Early Jan., 1906	0.58	1.51	50.09	47.82
900*b*	6 060	6 080	13 310		Late " 1906	0.27	2.12	43.44	54.17
901*b*	6 910	6 935	14 350		Early Feb., 1906	0.37	2.05	46.10	51.48
903*b*	6 935	6 988	13 880		Late " 1906	0.78	1.66	48.28	49.28
	7 054	7 091	13 878	Average, winter.....		0 54	1.86	48.97	48.03
	8 396	8 510	14 296	Average, all tests.....		1.34	3.73	55.00	39.93

Proximate Analyses (Welton).

Garbage. (25 Tests.)

Laboratory No.	Calorific Values.			From Collections Made:		Proximate Analyses.			
	Per pound, original sample. B. t. u.	Per pound, dry sample. B. t. u.	Per pound, combustible. B. t. u.	Season.	Month and year.	Moisture. Percentage.	Volatile matter. Percentage.	Fixed carbon. Percentage.	Ash. Percentage.
921*a*	2 535	8 633	10 490	Spring ...	March, 1906	70.63	19.76	4.40	5.21
922*a*	2 690	8 910	9 970		Early April, 1906	69.80	22.60	4.40	3.20
928*a*	2 459	8 500	10 365		Late " 1906	71.08	19.21	4.50	5.21
929*a*	2 195	8 205	9 492		Early May, 1906	73.24	18.57	4.55	3.64
936*a*	1 779	7 025	11 500		Late " 1906	74.69	11.23	4.23	9.85
	2 331	8 294	10 273	Average, spring.....		71.89	18.27	4.42	5.42
946*a*	3 029	8 510	10 700	Summer.	Early June, 1906	64.43	20.01	8.29	7.27
971*a*	2 238	8 235	10 440		Late " 1906	72.83	17.19	4.24	5.74
975*a*	2 329	8 560	10 550		Early July, 1906	73.43	18.11	3.97	4.49
976*a*	2 507	7 980	9 400		Late " 1906	68.59	21.38	5.30	4.73
994*a*	1 706	7 665	9 280		Early August, 1906	77.74	14.58	3.80	3.88
995*a*	2 076	8 950	10 460		Late " 1906	76.80	16.32	3.53	3.35
833*a*	1 753	8 985	10 770		July, 1905	80.50	14.68	1.59	3.23
	2 234	8 421	10 220	Average, summer.....		73.47	17.47	4.39	4.67
858*a*	2 190	8 533	10 550	Autumn.	September, 1905	74.31	16.75	4.03	4.91
998*a*	2 063	8 720	10 520		Early Sept., 1906	76.33	16.02	3.59	4.06
1 011*a*	1 652	7 720	9 450		Late " 1906	78.60	13.97	3.52	3.91
862*a*	2 189	8 228	10 120		Early Oct., 1905	73.40	11.62	10.00	4.98
875*a*	3 050	8 805	10 720		Late " 1905	65.35	21.18	7.27	6.20
882*a*	2 354	8 003	9 820		Early Nov., 1905	70.59	18.87	5.12	5.42
887*a*	1 719	6 065	10 275		Late " 1905	71.66	11.17	5.56	11.61
	2 174	8 022	10 240	Average, autumn.....		72.89	15.65	5.58	5.87
894*a*	2 580	7 955	10 160	Winter...	Early Dec., 1905	67.56	19.28	6.12	7.04
895*a*	1 807	8 750	10 390		Late " 1905	79.35	14.21	3.18	3.26
899*a*	2 009	9 570	11 180		Early Jan., 1906	79.01	14.28	3.67	3.04
900*a*	2 008	8 010	10 310		Late " 1906	74.93	14.84	4.63	5.60
901*a*	2 729	10 330	11 545		Early Feb., 1906	73.60	19.84	3.78	2.78
903*a*	2 192	8 106	10 375		Late " 1906	72.95	16.54	4.58	5.93
	2 221	8 734	10 668	Average, winter.....		74.57	16.50	4.32	4.61
	2 233	8 351	10 338	Average, all tests.....		73.26	16.89	4.71	5.14

TABLE 6.—CALORIMETER TESTS AND PROX-

RUBBISH. (26 TESTS.)

Laboratory No.	CALORIFIC VALUES. Per pound, original sample. B. t. u.	Per pound, dry sample. B. t. u.	Per pound, combustible. B. t. u.	FROM COLLECTIONS MADE: Season.	Month and year.	PROXIMATE ANALYSES. Moisture. Percentage.	Volatile matter. Percentage.	Fixed carbon. Percentage.	Ash. Percentage.
981c	7 070	7 360	8 385	Spring...	Early March, 1906	3.95	69.04	15.31	11.70
921c	6 999	7 233	9 330		Late " 1906	3.21	62.77	12.23	21.79
922c	6 395	6 555	8 692		Early April, 1906	2.46	60.94	12.64	23.96
928c	6 490	6 821	8 220		Late " 1906	4.74	64.49	14.52	16.25
929c	6 810	7 210	9 220		Early May, 1906	5.55	56.12	17.72	20.61
936c	7 220	7 690	8 370		Late " 1906	6.08	74.98	11.32	7.62
	6 831	7 140	8 682	Average, spring.....		4.33	64.72	13.96	16.99
946c	6 088	6 920	8 810	Summer.	Early June, 1906	7.13	52.60	16.52	23.75
971c	6 895	7 485	8 070		Late " 1906	7.90	70.46	15.06	6.58
975c	7 040	7 748	8 880		Early July, 1906	9.14	66.31	13.00	11.55
976c	7 028	7 463	7 950		Late " 1906	5.83	73.78	14.64	5.75
833c	6 308	6 870	7 230		July, 1905	8.20	75.60	11.70	4.50
994c	6 717	7 480	8 375		Early August, 1906	10.22	64.94	15.27	9.57
995c	6 780	7 330	8 175		Late " 1906	7.55	68.44	14.50	9.51
	6 694	7 275	8 179	Average, summer		7.99	67.45	14.39	10.17
858c	6 720	7 183	9 120	Autumn.	September. 1905	6.45	54.30	19.35	19.90
998c	5 360	5 687	7 880		Early Sept., 1906	5.74	51.84	17.20	25.22
1 011c	6 570	7 062	8 430		Late " 1906	6.97	63.06	14.91	15.06
862c	5 567	5 808	8 950		Early Oct., 1905	4.17	49.86	15.00	30.97
875c	7 130	7 575	8 170		Late " 1905	5.84	69.94	17.44	6.78
882c	7 742	8 343	8 910		Early Nov., 1905	7.16	72.68	14.26	5.90
887c	7 455	7 873	8 965		Late " 1905	5.34	67.81	15.37	11.48
	6 649	7 069	8 570	Average, autumn.....		5.95	61.36	16.22	16.47
894c	7 012	7 310	8 145	Winter...	Early Dec., 1905	4.04	71.06	15.00	9.90
895c	6 870	7 225	8 370		Late " 1905	4.90	69.07	13.06	12.97
899c	8 325	8 740	9 520		Early Jan., 1906	4.72	71.98	15.54	7.81
900c	6 250	6 510	7 985		Late " 1906	3.96	65.91	12.40	17.73
901c	7 280	7 580	8 750		Early Feb., 1906	3.88	70.50	12.75	12.87
908c	7 525	7 933	8 950		Late " 1906	5.10	68.90	15.20	10.80
	7 210	7 545	8 630	Average, winter.....		4.44	69.56	13.99	12.01
	6 832	7 251	8 503	Average, all tests.....		5.78	65.66	14.69	13.87

IMATE ANALYSES (WELTON).—(*Continued*).

OTHER TESTS.

Laboratory No.	CALORIFIC VALUES. Per pound, original sample. B. t. u.	Per pound, dry sample. B. t. u.	Per pound, combustible. B. t. u.	Material, etc.	PROXIMATE ANALYSES. Moisture, percentage.	Volatile matter, percentage.	Fixed carbon, percentage.	Ash, percentage.
923*f*	2 846	2 880	13 300	Fine ash. Screened from collections. 1905–1906.	1.20	4.02	17.38	77.40
1 031	1 578	1 583	10 038	Clinker. From collections 1905–1906.	0.32	0.73	14.99	83.96
892*e*	3 998	3 998	14 117	Ash. From practical tests in burning mixed refuse, December, 1905.	0.00	2.86	25.46	71.68
892*d*	900	900	8 730	Clinker. From practical tests in burning mixed refuse, December, 1905.	0.00	0.00	10.31	89.69
See 833*a* 833*b* 833*c*				Composite sample. Garbage.....58.4% by weight Coal and cinders. 27.0% " " Rubbish..... 19.6% " "				
833*d*	4 364	7 952	10 659	By test.	45.12	40.94		13.94
	4 294	7 823	10 613	By calculation. From Tests 833*a*, 833*b* and 833*c*.	45.11	26.63	13.83	14.43

appreciable seasonal variation, and "rubbish" has a higher power in winter than in spring, summer, or autumn. The test of a single average sample of "fine ash" and of "clinker" leaves the question of seasonal variations undetermined with regard to these materials. On the whole, the seasonal differences are not marked, except in the case of "coal and cinders." The columns giving the heat units per pound of dry sample show the variations in the mechanical analyses and the bulk sampling, while the calorific power per pound of combustible compares the character of the materials tested, and was used as an additional check in the calorimeter determinations. The results of the tests shown in Table 6 were much more consistent than was ever hoped for.

Based on the composition of refuse (Table 3) and the final calorific tests (Table 6), the heat value per pound of refuse for different periods has been deduced, as shown in Table 7.

TABLE 7.—CALORIFIC VALUE PER POUND OF REFUSE FOR DIFFERENT PERIODS.

Period.	Calorific power of combustible, B. t. u.	Moisture, per cent.	Ash, per cent.	Combustible, per cent.	Remarks.
Spring.....	4 747	14.03	50.06	35.91	Computed results based on average figures for corresponding periods in Tables 3 and 6, except that average calorific values for summer components were used in arriving at September results.
Summer....	3 477	28.86	39.74	31.40	
Autumn.....	3 833	27.74	39.74	32.52	
Winter.....	4 358	13.11	52.72	34.17	
Year.....	4 274	19.74	46.03	34.23	
September..	3 265	35.83	33.69	30.48	

Compared with the results computed from the preliminary calorific tests (Table 5), the values in Table 7 will be found to be considerably higher, due to including the combustible power of the "fine ash" and the greater heat value of "coal and cinders."

September has the minimum calorific power and the maximum amount of moisture, thus becoming the most trying month in burning mixed refuse.

V.—Practical Tests in Burning Refuse.—While other examinations were progressing, practical tests in burning refuse were conducted at

PLAIN SIGHT OF PLANT. AT THE RIGHT OF THE CHIMNEY.

PLATE XCIX.
PAPERS, AM. SOC. C. E.
NOVEMBER, 1907.
FETHERSTON ON
REFUSE DESTRUCTION.



FIG. 1.—BROMLEY DESTRUCTOR. HOUSES TO THE RIGHT.



FIG. 3.—SHOREDITCH DESTRUCTOR IS IN REAR OF CHAPEL. WITH BUILDINGS ON ALL SIDES.



FIG. 2.—BROMLEY DESTRUCTOR. RESIDENCES NEARBY—IN PLAIN SIGHT OF PLANT.

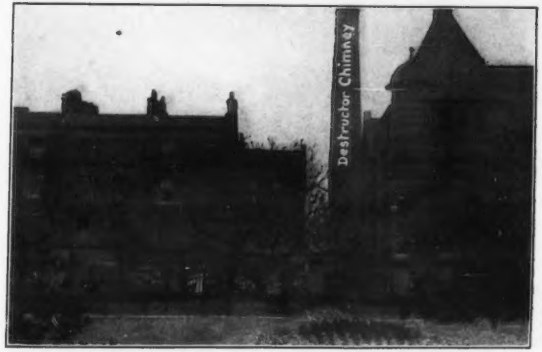


FIG. 4.—ANOTHER VIEW AT SHOREDITCH. THE DESTRUCTOR IS AT THE RIGHT OF THE CHIMNEY.

the West New Brighton crematory. The coal grate of the Dixon garbage furnace (12 sq. ft. in area) was used for burning the materials. Air at atmospheric temperature was forced into the ash-pit by a Sturtevant fan driven by an electric motor. Paper and wood, reduced to a glowing mass on the grate, were used to start the fire, except where otherwise noted in Table 8, which summarizes the results of forty-two trials, with other experimental data. In spite of such adverse conditions as cold air blast, cold furnace walls, leakage of air through warped doors, and high percentage of moisture, with small amount of combustible in some trials, all the tests except one were successful in destroying mixed household refuse, though unburned particles were at times found in the residue.

The general deductions from these rough practical tests may be summed up as follows:

1.—Household refuse, as collected in this district, when burned in a properly designed furnace, will be self-combustible, under ordinary conditions, showing higher calorific power in winter than in summer. Screened refuse will give better results in burning than unscreened.

2.—About 80 lb. of refuse per sq. ft. of grate could be burned before it became necessary to remove the clinker.

3.—The process may be made continuous by retaining the heated coals from the top portion of the fire and removing the mass clinker. Coal may be required to heat the furnace walls if the operation of the plant is not made continuous.

4.—The rate of burning will be higher in summer than in winter.

5.—The percentage of clinker will also vary with the seasons, being high in winter and low in summer. The total residue was not determined, as a large portion of the fine ash was carried over by the air blast and could not be recovered.

6.—The heat lost by the removal of hot clinker varied from 300 to 500 B. t. u. per lb. of clinker.

7.—Street sweepings from this locality could not be burned with household refuse, except when mixed in small proportions.

VI.—Power from Refuse—Temperatures.—In spite of the fact that British engineers have had years of experience with refuse destructors, the writer has been able to find only one scientific test which would assist in determining the actual power to be obtained from refuse of known calorific value. Mr. C. E. Stromeyer (in January,

TABLE 8.—PRACTICAL TESTS

Test No.	Date. 1905.	Kind of material burned.	Amount of refuse, in pounds.	Time burning, in minutes.	Rate of burning, per square foot of grate, per hour.	Temperature or appearance of fire.	Air pressure in ash-pit. Inches of water.	Chimney smoke.
1	Apr. 16.	Composite sample "*A*".....	500	51	49	Short orange to yellow flame.	.....	Hardly visible except when feeding.
2	"	Composite sample "*B*"....	500	40	62½	" " "	.....	" " "
3	"	Mixed refuse as collected..	1 000	20	.....	Smoke. No flame. Fire smothered.	.....	.....
4	"	" "	1 000	60	83.3	Short yellow to white flame.	.....	Hardly visible except when feeding.
5	Apr. 23.	" "	1 600	90	88.8	Short yellow to white flame, 800 to 1 200° fahr.	1½	Dense white at start. Hardly visible later.
6	Apr. 30.	" "	470	37	63.5	800-1 200° fahr. Melted lead, zinc and aluminum.	¾	Light white smoke.
7	"	" "	470	50	....	Fire failed to spread.	¾	.....
8	May 28.	" "	500	37	67.5	800° fahr.	¾	Light white smoke.
9	"	Composite sample "*C*"....	1 000	90	55.5	1 200° fahr.	¾	Dense to light white smoke.
10	June 25.	Mixed refuse as collected..	1 100	90	61	Yellow to white flame.	1½	" " "
11	July 9.	" "	.....	.....	.....	.....	.....	Murky smoke at start, then light white.
11		Material in rain overnight. Contained 37.5% moisture.	.....	.....	.....	.....	.....	.....
12	July 23.	Mixed refuse as collected..	950	60	79	800°-1 200° fahr.	1	Light white to hardly visible smoke.
13	Aug. 6.	Composite sample "*D*".....	500	....	.....	Clear hot fire..	¾	Light white smoke.
14	"	" " "*E*'.....	300	....	.....	Fire smothered.	1½	" " "
15	Aug. 20.	Mixed refuse as collected..	1 500	90	83.3	Clear hot fire.	1½	Murky at start. Hardly visible later.
16	Sept. 10.	" "	1 431	....	.....	Poor fire. Low temperature.	1	Murky to white dense smoke.
17	Sept. 17.	" "	1 126	60	94	Low temperature.	1½	Murky to light white.
18	Sept. 24.	" "	986	60	82	1 000° fahr.	¾	Dense to light white smoke.
19	Oct. 1.	" "	1 547	90	86	Above 1 200° fahr.		Light white to hardly visible.

IN BURNING REFUSE.

Residue (excluding dust).							
Clinker.		Ashes.		Total residue.			Notes.
Weight, in pounds.	Percentage.	Weight, in pounds.	Percentage.	Weight, in pounds.	Percentage.	Character of clinker.	
179	35.8	.....	.....	.....	.....	Vitreous.....	Refuse ignited on bed of hot coals. Two charges of 250 lb. each. Burned freely.
231	46.2	.....	.....	.....	.....	"	Hot furnace walls. Material burned freely.
.....	.....	.....	.....	.....	.....	.....	Refuse not properly ignited. Too much air from blast.
301	30.1	.....	.....	.....	.....	Vitreous. Well burned.	Same material as in 3. Started properly. Burned freely.
379	23.7	107	6.7	486	30.4	" "	Material burned freely.
137	29.2	.....	.....	.....	.....	" "	Material burned freely. One-half of grate clinkered, other half of clinker spread to start Test 7.
.....	.....	.....	.....	.....	.....	.....	Clinker from former test failed to ignite fresh refuse.
140	28	43	8	183	36.6	Vitreous.....	Material burned freely.
329	33	87	9	416	42	Dense vitreous clinker.	Hot furnace walls from Test 8. Material burned freely. Clinker very hard and dense.
378	34.4	.....	.....	.....	.....	Vitreous.	Test to determine amount of refuse that could be burned before clinkering became necessary. Result—about 80 lb. per sq. ft. of grate.
.....	.....	.....	.....	.....	.....	.....	Test to determine amount of kindlings necessary to ignite the refuse properly. First—20 lb. of paper was tried with partial success.
.....	.....	.....	.....	.....	.....	.....	Second—11 lb. paper, 50½ lb. wood used. Material burned freely.
.....	.....	.....	.....	.....	.....	.....	Much smoke in furnace room during both trials—due to moisture in refuse.
269	28.3	.....	.....	.....	.....	Vitreous	Refuse in rain over-night. Contained large quantity of garbage, grass, weeds and paper. Very little ashes.
.....	.....	.....	.....	.....	.....	.....	Burned freely. Clinker apparently very dense.
.....	.....	.....	.....	.....	.....	.....	Charged on Test 14 when "*D*" was burned down to glowing mass. Fire smothered by sweepings in "*E*."
477	31.8	136	9.0	613	40.8	Vitreous	Refuse mostly green vegetable matter with small amount of ashes and rubbish.
.....	.....	.....	.....	.....	.....	No clinker formed.	Refuse contained much wet sawdust, decayed fish and vegetables from stores. Moisture 56.5%. Not completely burned. Very smoky in furnace room.
317	28.1	.....	.....	.....	.....	Fair. Not dense. Material not all burned.	Large amount of yard sweepings in refuse, very little combustible. Too much air from blower.
364	26.8	.....	.....	.....	.....	Small amount of clinker. Mostly ashes on grate.	Large quantity garbage, small amount of ashes and rubbish. Less air than in 17 with better results. Not much clinker formed.
379	24.5	125	8	504	32.5	Vitreous. Well burned.	Material from residential section. Large amount of ashes.

TABLE 8—PRACTICAL TESTS

Test No.	Date. 1905.	Kind of material burned.	Amount of refuse, in pounds.	Time burning, in minutes.	Rate of burning, per square foot of grate per hour.	Temperature or appearance of fire.	Air pressure in ash-pit. Inches of water.	Chimney smoke.
20	Oct. 15.	Mixed refuse as collected..	1 495	80	93	Above 1 200° fahr.	1½	Light white to hardly visible.
21	Oct. 29.	" "	1 254	80	78.4	" " "	1½	" " "
22	Nov. 12.	" "	1 148	120	47.8	" " "	1	" " "
23	Nov. 26.	" "	1 159	90	64.4	" " "	1	" " "
24	Dec. 10.	" "	1 559	125	62.4	" " "	1½	Murky at start. Hardly visible later.
	1906.							
25	Jan. 7.	" "	1 200	90	66.6	Temp. low.	Gauge broken.	Light white smoke.
26	Jan. 21.	" "	1 128	60	94	Temp. low.	"	Murky at start. Hardly visible later.
27	Feb. 4.	" "	1 120	70	80	Above 1 000° fahr.	"	Light white at start. Not visible later.
28	Feb. 18.	" "	1 180	90	74	Above 1 200° fahr.	"	Murky at start. Hardly visible later.
29	Mar. 11.	" "	1 500	90	83.3	Temp. by pyrometer 1 600° fahr.	"	Light white at start. Hardly visible later.
30	Mar. 25.	" "	1 000	90	55.5	Combustion chamber temp. by pyrometer 1 100° fahr.	"	Light white to hardly visible.
31	Apr. 8.	" "	1 335	90	74.2	Highest temp. 1 420° fahr.	"	White at start. Not visible later.
32	Apr. 22.	" "	1 200	75	80	Highest temp. 1 400° fahr.	"	Light white at start. Not visible later.
33	May 6.	" "	1 200	75	80	Highest temp. 1 350° fahr.	"	Light white at start. Hardly visible later.
34	May 20.	" "	1 200	60	100	Highest temp. 1 150° fahr.	"	Dense white at start.
35	June 3.	" "	1 100	75	73.3	Highest temp. 1 320° fahr.	"	Light white smoke.
36	June 17.	" "	1 280	70	91.4	Highest temp. 1 400° fahr.	"	Light white at start. Not visible later.
37	July 8.	" "	1 880	....	.....	Highest temp. 1 400° fahr.	"	Light white at start.
38	July 22.	" "	1 400	....	.....	Highest temp. 1 300° fahr	"	Heavy white at start.
39	Aug. 5.	" "	1 250	115	.....	Highest temp. 1 400° fahr.	"	Dense white at start. Light white later.
40	Aug. 19	"	1 100	60	92	Temp. high. 1 700° fahr.	"	Light white smoke.
41	Sept. 2.	"	1 030	60	86	Highest temp. 1 350° fahr.	"	Dense white at start.
42	Sept. 23.	" "	1 200	75	80	Highest temp. 1 400° fahr.	"	Dense white at start. Hardly visible later.

IN BURNING REFUSE—(*Continued.*)

Residue (excluding dust).							
Clinker.		Ashes.		Total residue.		Character of clinker.	Notes.
Weight, in pounds.	Percentage.	Weight, in pounds.	Percentage.	Weight, in pounds.	Percentage.		
326	21.8	90	6	416	27.8	Vitreous. Well burned.	Large quantity of green vegetables and decayed fish. Burned rapidly.
327	26	73	6	400	32	" " "	Large proportion of fine ash and vegetables, very little rubbish.
432	37.6	82	7.2	514	44.8	" " "	Large amount of garbage and fine ash.
334	28.8	87	7.5	421	36.3	" " "	Large proportion of fine ash, small amount of coal and cinders.
564	36.2	181	11.6	745	47.8	" " "	About half of refuse burned down, mass clinkers then removed and other half of refuse charged on coals of first fire.
							Material burned freely in both cases.
.....	.....	.....	.....	.....	.....	Poor. No mass clinker. Mostly ashes.	Poor quality of material. Large amount of incombustible. Residue not completely burned.
							Material poor in quality.
.....	.....	.....	.....	.....	.....	Rather poor.....	Purpose of test—to determine the amount of waste heat in clinker. 511 B. t. u. per lb.
							Material of fair quality.
.....	.....	.....	.....	.....	.....	Hard. Well burned.	Waste heat in clinker, tested, gave 315 B. t. u. per lb.
367.5	31.1	141	12.0	508.5	43.1	Hard. Well burned.	Refuse of fair quality. Waste heat from residue on grate gave 488 B. t. u. per lb.
518	34.5	132	8.8	650	43.3	Hard. Well burned.	Bristol electric pyrometer used for taking temperature readings. Combustion chamber 1 600° F. Chimney 1 000°
478	47.8	80	8.0	558	55.8	Hard. Well burned.	Fire not well started. Excess of air.
421	31.5	88	6.6	509	38.1	Hard. Well burned.	Material wet. In rain over-night. Furnace room smoky.
290	24.2	161	13.4	451	37.6	Hard. Well burned.	Refuse dry, large quantity of fine ash.
293	24.4	100	8.3	393	32.7	Hard. Well burned.	Refuse damp. Burned rapidly.
302	25.2	63	5.2	365	30.4	Poor. Little mass clinker.	Fire poorly started. Much smoke from furnace. Excess of air.
219	19.9	115	10.5	334	30.4	Fair	Excess of air.
308	24.1	115	9.0	423	33.1	Hard. Well burned.	Material burned rapidly. Probable excess of air.
.....	.....	.....	.....	.....	.....	.....	Electric motor broke down. Test not finished. Material of very poor quality—very wet.
.....	.....	.....	.....	.....	.....	.....	Test not finished. Belt to fan broke. Material in rain over-night.
.....	.....	.....	.....	.....	.....	.....	Material practically all garbage, contained 40% water. Required coal to burn it properly.
259	23.5	108	9.8	367	33.3	Well burned. Not much mass clinker.	Material burned freely. High tem. Clinker cooled in air dropped 1 360° fahr. in 40 min.
212	20.6	57	5.5	269	26.1	Not much lump clinker.	Some unburned corncobs in ashes. Clinker cooled by fan blast dropped 1 280° fahr. in 20 min. Excess air.
272	22.7	73	6.0	345	28.7	Not much lump clinker. Not completely burned.	Unburned corncobs and wood. Excess of air. Test to determine temp. to which air could be heated by hot clinker. See Note 42.

TABLE 8—PRACTICAL TESTS IN BURNING REFUSE.—(*Continued.*)

Composition of Refuse Burned.

Test No. 1. Composite "A."

Coal and cinders	208 lb.	= 41.6%
Rubbish	31½ "	= 6.3 "
Clinker	45½ "	= 9.1 "
Garbage	194 "	= 38.8 "
Glass, metals, etc.	21 "	= 4.2 "
Totals	500 "	100 "

Test No. 2. Composite "B."

Coal and cinders	145 lb.	29%
Rubbish	20 "	4 "
Clinker	35 "	7 "
Garbage	265 "	53 "
Glass, metals, etc	35 "	7 "
Totals	500 "	100 "

Tests 3 and 4. Sample.

Coal and cinders	60 lb.	37.5%
Garbage	13 "	8.1 "
Rubbish	4 "	2.5 "
Glass, metals, etc.	3 "	1.9 "
Clinker	7 "	4.4 "
Fine ash	73 "	45.6 "
Totals	160 "	100 "

Test 5. Sample.

Coal and cinders	68 lb.	46.3%
Garbage	17 "	11.5 "
Rubbish	11.5 "	7.8 "
Glass, metals, etc.	4.5 "	3.0 "
Clinker	5 "	3.4 "
Fine ash	41 "	28.0 "
Totals	147 "	100 "

Moisture test, 112 hr. drying.

Weight, original sample	56 lb.
" dried "	45 "
Water evaporated	11 "

Moisture, 19.6%.

Tests 6 and 7. Sample.

Coal and cinders	11.5 lb.	27.0%
Garbage	10 "	23.6 "
Rubbish	2 "	4.7 "
Glass, metals, etc.	1.5 "	3.5 "
Clinker	0.5 "	1.2 "
Fine ash	17 "	40.0 "
Totals	42.5 "	100 "

Moisture test, 112 hr. drying.

Weight, original sample	42.5 lb.
" dried "	33.5 "
Water evaporated	9.0 "

Moisture, 21%.

Test 8. Sample.

Fine ash	18 lb.	31%
Coal and cinders	13 "	22 "
Rubbish	6 "	10 "
Garbage	16 "	28 "
Glass, metals, etc.	5 "	9 "
Totals	58 "	100 "

Moisture test, 112 hr. drying.

Weight, original sample	42 lb.
" dried "	35 "
Water evaporated	7 "

Moisture, 16.6%.

Test 9. Composite "C."

Coal and cinders	243 lb.	24.3%
Clinker	81 "	8.1 "
Glass, metals, etc.	19 "	1.9 "
Garbage	480 "	48.0 "
Rubbish	177 "	17.7 "
Totals	1 000 "	100 "

Test 10. Sample.

Coal and cinders	27 lb.	22.7%
Rubbish	9 "	7.6 "
Glass, metals, etc.	6 "	5.0 "
Garbage	23 "	19.3 "
Clinker	4 "	3.4 "
Fine ash	50 "	42.0 "
Totals	119 "	100 "

Sample of material from Test 10 showed 5 700 B. t. u. on dry refuse. (See Table 5, Lab. No. 6 918.)

Test 11. Moisture Test.
96 hr. drying.

Weight, original sample	32 lb.
" dried "	20 "
Water evaporated	12 "

Moisture, 37.5%.

TABLE 8—PRACTICAL TESTS IN BURNING REFUSE.—(*Continued.*)

Composition of Refuse Burned.

Test 14. Composite "E."

Coal and cinders	60.75 lb.	12.1%
Clinker	20.25 "	4.1 "
Glass, metals, etc	4.75 "	1.0 "
Garbage	120.00 "	24.0 "
Rubbish	44.25 "	8.8 "
Street sweepings	250.00 "	50.0 "
Totals	500 "	100 "

Test 13. Composite "D."

Coal and cinders	121.5 lb.	24.3%
Clinker	40.5 "	8.1 "
Glass, metals, etc	9.5 "	1.9 "
Garbage	240.0 "	48.0 "
Rubbish	88.5 "	17.7 "
Totals	500 "	100 "

Test 24. Sample.

Fine ash	52.0 lb.	45.8%
Clinker	7.0 "	6.2 "
Glass, metals, etc	4.5 "	3.9 "
Coal and cinders	33.5 "	29.5 "
Garbage	13.0 "	11.5 "
Rubbish	3.5 "	3.1 "
Totals	113.5 "	100 "

Test 16. Moisture Test.
96 hr. drying.

Weight, original sample	23 lb.
" dried "	10 "
Water evaporated	13 "

Moisture, 56.5%.

Test 32. Moisture.

Weight, original sample	23.5 lb.
" dried "	21.0 "
Water	2.5 "

Moisture, 10.7%.

Test 34. Sample.

Fine ash	23 lb.	29.1%
Coal and cinders	28 "	35.4 "
Clinker	4 "	5.1 "
Rubbish	8 "	10.1 "
Garbage	16 "	20.3 "
	79 "	100 "

Moisture test.

Original sample	32 lb.
Dried "	26 "
Water	6 "

Moisture, 19%.

Test 35. Moisture.

Original sample	35 lb.
Dried "	29 "
Water	6 "

Moisture, 17.2%.

Test 36. Moisture.

Original sample	35 lb.
Dried "	28 "
Water	7 "

Moisture, 20%.

Test 38. Moisture.

Original sample	35 lb.
Dried "	28 "
Water	7 "

Moisture, 20%.

Test 39. Moisture.

Original sample	30 lb.
Dried "	18 "
Water	12 "

Moisture, 40%.

Test 40. Estimated composition.

Ashes	60% by weight.
Garbage	30 " " "
Rubbish	8 " " "
Tins, etc	2 " " "

Note.—Hot clinker from grate cooled 1 300° fahr. in air, in 40 min.

Test 41. Estimated composition.

Ashes	50% by weight.
Garbage	30 " " "
Rubbish	15 " " "
Tins, etc	5 " " "

Note.—35 lb. hot clinker was cooled from 1 700° fahr. to 420° fahr. (1 280° fahr.) by air blast in 20 min.

Test 42. Estimated composition.

Garbage	60% by weight.
Ashes	30 " " "
Rubbish	7 " " "
Tins, etc	3 " " "

Note.—Air at 84° fahr. was heated to 423° in passing through hot clinker. After 5 min. the air forced through the hot clinker by the fan dropped from 423° to 270° fahr. 74 lb. of clinker with large volume of air was used.

TABLE 8.—PRACTICAL TESTS IN BURNING REFUSE.—(*Continued*).

Summary Showing Residue from Tests.

Season.	Refuse burned, in pounds	Time of burning, in minutes.	Rate of burning, per square foot of grate per hour.	Residue.			
				Clinker.		Ashes from Ash-pit.	
				Pounds.	Percent.	Pounds.	Percent.
Spring.....	9 535	607	78.5	2 821	29.6	774	8.1
Summer.....	4 980	295	84.5	1 263	25.4	474	9.5
Autumn.....	8 833	595	74.0	2 282	25.8	587	6.7
Winter.....	2 739	215	63.5	932	34.0	322	11.7
Year.....	26 087	1 712	76.0	7 298	28.0	2 157	8.3

1903), by continuous gas analysis, made an economic test and worked out a heat balance for the destructor at Nelson, England. Guided by some of the results of this test, and based upon the experience gained and experiments made in the burning of local mixed refuse, the writer has arranged the approximate heat balance shown in Table 9.

Column 12 in Table 9 answers the question (approximately and theoretically) as to the probable evaporative power of local refuse when burned in an up-to-date destructor, and Column 13 shows the estimated temperature of the combustion chamber under the assumed conditions of burning.

The calculated evaporative power of local refuse is generally higher, and shows a greater seasonal variation than that indicated by published tests with British refuse. September remains the critical month in destroying the material.

Summarizing the results of examinations, tests, and experiments with mixed household refuse from the district considered, the following conclusions are derived:

1.—Average local refuse differs mainly from what is known concerning average English refuse in the higher percentage of incombustible matter and the lower percentage of water. The average results to be expected in power production are surprisingly high, and the seasonal variations are greater with local refuse than with British refuse.

2.—Under expert management, with a properly designed furnace, the process can be carried out in settled communities without nuisance.

TABLE 9.—APPROXIMATE HEAT BALANCE PER POUND OF REFUSE. ESTIMATED TEMPERATURES.

Period. (1)	Calorific power of refuse, in B. t. u. (2)	Losses due to: Moisture, in B. t. u. (3)	Heat in dry chimney gases, in B. t. u. (4)	Unburned carbon in clinker, in B. t. u. (5)	Unburned carbon in ashes, in B. t. u. (6)	Heat in clinker, in B. t. u. (7)	Forced draft, in B. t. u. (8)	Radiation, etc., in B. t. u. (9)	Total losses, in B. t. u. (10)	Net useful heat to boiler, in B. t. u. (11)	Equivalent evaporation, from and at 212° fahr. (useful steam), pounds of water. (12)	Estimated temperature of combustion chamber, in degrees Fahrenheit. (13)
Spring	4 747	184	465	266	324	55	121	949	2 364	2 383	2.46	2 270
Summer	3 477	373	407	229	380	38	106	695	2 228	1 249	1.29	1 710
Autumn	3 893	393	421	282	298	44	110	797	2 305	1 588	1.68	1 950
Winter	4 358	174	443	306	468	63	115	872	2 441	1 917	1.98	2 140
Year	4 274	259	444	252	332	54	116	885	2 312	1 962	2.03	2 150
September	3 295	405	395	229	390	54	108	653	2 279	986	1.02	1 550

3.—The average local residue will be greater than the average English residue mainly because of the high percentage of fine ash which will to some extent be carried away from the fire-grate by the forced draft.

4.—As compared with the local cost of burning garbage and caring for "ash and rubbish" dumps, the cost of the destruction of mixed refuse will probably be higher, though a proper utilization of the steam generated and the clinker resulting may offset this increase in cost, while a rearrangement of the refuse collection system may tend further to make the cost of the methods comparable.

5.—For the particular conditions herein considered, mixed-refuse destruction appears to offer the best solution of the problem.

PART II.

Pending the acquisition of property for the erection of the first installation, the writer was directed by the President of the Borough of Richmond to examine a number of British refuse destructors in actual operation, so that the various reports might be verified and the differences in composition, quantity, and quality of refuse noted, in addition to obtaining data whereby the best type of modern destructor could be secured. Particular instructions were given to observe the weak points in mixed-refuse destruction.

During May and June, 1906, thirty-nine installations in Great Britain were inspected, and in August, 1906, the only destructor of the British type in the eastern part of North America, at Westmount, a suburb of Montreal, Canada, was visited in company with Louis L. Tribus, M. Am. Soc. C. E., Consulting Engineer to the President of the Borough of Richmond. Thus forty destructors were examined, thirty of which were in England, three in Wales, three in Ireland, three in Scotland, and one in Canada.

In covering a large field, wherein variations in type and design of destructors burning different kinds of refuse were encountered, a better general knowledge of the results attained in disposing of refuse was secured than if attention had been concentrated on a smaller number of plants.

Efforts were made to obtain complete data following a schedule covering the main factors in the process of mixed-refuse destruction, so that the various features of each installation might be tabulated

Reference Number.	Date visited; municipality; population; and area.	General character of population.	Collection of refuse.		Opinion on Character of Refuse.					Location of plant.	Type and description.	Erected.	Rated capacity in tons, (2 240 lb.) per 24 hours.	
					Estimated composition by weight.				Apparent value as a fuel.					
			Frequency.	Cost per long ton.	Ashes.	Garbage.	Rubbish.	Glass, metal, etc.	Note.—British refuse is dark brown to black in color—due to ash from bituminous coal.					
					%	%	%	%						
1	May 3, 1906; Borough of Fulham, London, Eng.; Pop., 156 000; Area, 1 701 acres.	Poor people generally; crowded.	.....	.....	65	10	10	15	Fair. No lump coal visible—mainly fine ash—rather moist...	Isolated. Houses 600 to 800 ft. off. Corporation yard.....	*Horsfall.* Standard, back to back, 12 cells, top-feed, 6 Babcock and Wilcox boilers, steam-jet blowers, heated air, chimney, 100 ft. by 8 ft. 6 in., dust catcher.....	1901	120	The 6 twe are eco cru pla
2	May 4, 1906; Bromley Municipal Corporation, Eng.; Pop., 27 354; Area, 4 706 acres.	Suburban; residential.	.....	.....	40	40	10	10	Poor. No lump coal—mainly fine ash. Large quantity of garden refuse.	Central. Workmen's houses 100 ft. off. General corporation yard	*Horsfall.* Top-feed by direct cart system. 3 cells, single row, 1 B. & W. boiler, steam-jet blowers, heated air, dust catcher	1904	45	Brick cle Clin lan hois asy plau exi
3	May 5, 1906; St. Pancras Borough, London, Eng.; Pop., 235 317; Area, 2 673 acres.	Poor people—business and manufacturing; crowded districts.	.....	.....	75	10	10	5	Fair. Mainly fine ash and rubbish in sight. No lump coal.....	Central. Houses and stores 400 ft. off on two sides	*Warner.* Top-feed, hopper or bin storage, 18 cells, back to back. 1 Hornsby boiler, fan draft, using cold (atmospheric) air.....	1894 1895	145	Brick by wor tong cap bui and
4	May 8, 1906; Epsom Urban District Council, Eng.; Pop., 14 000; Area, ...	Suburban; residential; village stores, etc.	Tri-weekly..	.....	65	15	10	10	Fair. Quite some garden refuse in sight..	Isolated. At sewage farm. Houses 1 000 ft. away	*Meldrum.* Two units of 2 grates each, front hand-feed, 2 Cornish boilers, steam-jet blowers, heated air.....	1904	48 Burning 10 tons per day.	Two one ney brin and ing
5	May 8, 1906; Watford Urban District Council, Eng.; Pop., 35 000; Area, ...	Suburban; residential town of the better class.	Bi-weekly...	.....	50	30	15	5	Fair. Quite some green garden refuse and garbage. No lump coal.....	Isolated. Houses on one side 300 ft. away. On outskirts of town.....	*Meldrum.* 1 unit of 4 grates, front hand-feed, 1 Lancashire boiler, steam-jet blowers, heated air.....	1903	48 Burns 24 tons per day.	Brick and Inv roo wi and bui
6	May 9, 1906; Wandsworth Borough, London, Eng.; Pop., 285 433; Area, 14½ sq. miles.	Mixed; poor people mainly.	Weekly	.....	.....	.....	.....	.....	No refuse in sight.....	Central. Workmen's houses on two sides, 100 ft. off. General corporation yard.....	*Meldrum, Beaman & Deas.* Top-feed by direct cart charging, 4 cells, 1 B. & W. boiler, fan draft, with cold air. Chimney, 150 ft.....	1899	70	Subst chi roa
7	May 9, 1906; City of London, Letts Wharf Destructor; Resident Pop., 26 933; Business Pop., 300 000; Area, 673 acres.	Business; mainly stores, offices, etc.	.....	.....	.....	.....	.....	.....	Refuse mainly rubbish with very little ashes or garbage.....	Central. At corporation yard on banks of Thames River.....	*Fryer.* Top-feed, 10 cells, 1 multitubular boiler, natural draft. Chimney, 150 ft. high.	1884	.....	Cells dor rem Ma
8	May 9, 1906; Westminster Borough, London, Eng.; Pop., 177 321; Area, 2 502 acres.	Fashionable quarter; residences British officials, government buildings, parks; also a poor district; wealthy residents generally.	.....	.....	.....	.....	.....	.....	Refuse in sight mainly rubbish and garbage.	Central. At Shot Tower Wharf on banks of Thames. Corporation yard	*Horsfall.* Top-feed, direct cart charged. 6 cells, 1 B. & W. boiler, steam-jet blowers, heated air, induced fan draft, dust catcher. Chimney, 90 ft. high.....	1900	72	Corr sto gro by rai gro sit

TABLE 10—Refuse Destructors Visited in England,

of plant.	Data on Plant.					Data from builders or destructo	
	Type and description.	Erected.	Rated capacity in tons, (2 240 lb.) per 24 hours.	Appurtenances.	Power utilized for:	Cost of construction: (a) Complete. (b) Building. (c) Chimney. (d) Destructor, with boiler and accessories.	Cost of op per long refuse bu (a) Labor. (b) Superv (c) Intere (d) Sinkin (e) Repair (f) Total.
uses 600 to Corpora-	*Horsfall.* Standard, back to back, 12 cells, top-feed, 6 Babcock and Wilcox boilers, steam-jet blowers, heated air, chimney, 100 ft. by 8 ft. 6 in., dust catcher	1901	120	The 6 B. & W. boilers are set between two blocks of 6 cells, and are arranged for coal firing. An economizer in use. Clinker crusher, sorter, flag and brick plant in an adjoining building..	Electric lighting and works purposes	(a) £16 760 $82 124 (c) £962 $4 714 (d) £11 113 $54 454 (b) £4 685 $22 956	Year 1 (a) 1s. 38. (b) (e) 2.8 4.0
Workmen's ft. off. Corporation	*Horsfall.* Top-feed by direct cart system. 3 cells, single row, 1 B. & W. boiler, steam-jet blowers, heated air, dust catcher	1904	45	Brick chimney 100 ft. by 5 ft. 9 in. Clinker railway. Elevator for hoisting loaded carts to tipping platform. Inclined roadway for exit of empty carts	Works purposes. Only partly utilized	(a) £4 890 $23 961	.....
uses and ft. off on	*Warner.* Top-feed, hopper or bin storage, 18 cells, back to back. 1 Hornsby boiler, fan draft, using cold (atmospheric) air	1894 1895	145	Brick chimney 207 ft. high used also by adjoining electric light station—said to be of insufficient capacity. Substantial brick buildings. Mortar mills, clinker and stone crushing plants in use.	Works purposes. Only one-third of power used	(a) £21 000 $102 900	(a) 1s 28
At sewage uses 1 000	*Meldrum.* Two units of 2 grates each, front hand-feed, 2 Cornish boilers, steam-jet blowers, heated air	1904	48 Burning 10 tons per day.	Two independent units, each with one Cornish boiler. Brick chimney 60 ft. high. Substantial brick building. Sewage pumps and air compressors in adjoining room	Sewage pumping. 600 000 gal. of sewage lifted 83 ft. Only part of power used	(a) £4 510 $22 100	(a) (e)
uses on one away. On f town	*Meldrum.* 1 unit of 4 grates, front hand-feed, 1 Lancashire boiler, steam-jet blowers, heated air	1903	48 Burns 24 tons per day.	Brick chimney 170 ft. high. Brick and corrugated iron building. Inward ventilation of furnace room. Pumping machinery with reserve coal-fired boilers and air compressors in separate building 50 ft. away	Sewage pumping. About 1 500 000 gal. of sewage pumped per day. Lifts of 25, 35, 84 ft.	(a) £6 800 $33 320 (b) £1 250 $6 125 (d) £3 500 $17 150	(a)+(b)
Workmen's two sides, . General n yard	*Meldrum, Beaman & Deas.* Top-feed by direct cart charging, 4 cells, 1 B. & W. boiler, fan draft, with cold air. Chimney, 150 ft.	1899	70	Substantial brick building and chimney. Solid filled inclined roadway	Works purposes	(a) £5 005 $24 524 (excluding inclined roadway.)	(a)
orporation banks of ver	*Fryer.* Top-feed, 10 cells, 1 multitubular boiler, natural draft. Chimney, 150 ft. high.	1884	.....	Cells out of repair and now abandoned as refuse station is to be removed to another locality. Material now being barged away	.....	.....	.....
Shot Tower banks of Corporation	*Horsfall.* Top-feed, direct cart charged, 6 cells, 1 B. & W. boiler, steam-jet blowers, heated air, induced fan draft, dust catcher. Chimney, 90 ft. high	1900	72	Corrugated iron building. Cart storage. Clinkering floor below ground level. Clinker removed by skips running on overhead rail and elevated by power to ground level. Very restricted site	Works purposes	(a) £10 241 $50 181	(a) 1 (e)

				Operation of Plant—Observations.				Utilization of By-Products.				
a from builders or operators of destructors.												
on- n: lete. ing. ney. ctor, r and ies.	Cost of operation per long ton of refuse burned. (a) Labor. (b) Supervision. (c) Interest. (d) Sinking Fund. (e) Repairs. (f) Total.	Refuse burned per man per hour. Long tons (2 240 lb.)	Special notes on plant.	Feeding—Stoking.	Clinkering—Character of clinker.	General notes.	Approximate temperature of main flue at time of visit, in degrees, Fahrenheit.	Clinker.	Flue dust.	Tins, etc.	Reported evaporation per pound of refuse, from and at 212° fahr.	Nuis possibl of co
760 124 2962 714 113 454 685 956	Year 1902. (a) 1s. 6.88d 38.7 cts. (b) 1.44d 2.88 cts. (e) 2.02d 4.04 cts.	1+	Clinker utilization plant cost £750 ($3 675). Refuse carries day load of lighting station.....	Top-feeding from storage hopper. Stoking through clinkering doors...	Clinkering hot, heavy work. Clinker hard. Some smoke from clinker doors.	Interior of building dusty, from dumping into hoppers and clinkering. Clinker yard very dusty—wind blowing dust about.	1 800	Crushed, screened, and made into slabs or bricks. Sold at 1s. 6d. (37 cts.) per ton.....	.....	Sold.....	1.53 lb. during a run of 13 days in October, 1905	None..
890 961	.....	1	Cremating chamber for dead animals, etc Water-sealed top-feeding doors. Cart storage of refuse	Direct feeding from cart. Stoking from clinker doors.....	Clinkering hot work. Clinkers not very hard.....	Building clean and well kept. Plant working under easy conditions. Some dust while clinkering.....	1 800	Part sold, rest used for road bottoming, etc.....	.....	Sold.....	.....	None ..
1 000 2 900	(a) 1s. 1¾d 28½ cts.	¾	Repairs to plant under way when visited.....	Top-feeding through open ports. Smoke escaping through feed ports. Stoking through clinker doors.....	Clinkering difficult—poor air and light space. Clinker poor in quality....	Cramped working space at clinkering floor. Smoke and odors from clinker yard	Low—About 1 200 to 1 400	Carted off or made into mortar.....	.....	.....	.....	Odor ker tem
4 510 2 100	(a) 11d 22 cts. (e) No repairs.	½	No inclined roadway—carts dump on floor in rear of furnaces....	Front-feeding easily done. Good light and air for firemen.	Clinkering hot work. Clinker hard	Plant well operated. Very little dust about. Furnaces working under easy conditions. Storage of refuse on floor inadvisable.....	1 800	Hand-broken and used for mortar making and bacteria beds. Revenue, £180 ($911) per annum.....	.....	.....	.....	None.
6 800 3 320 1 250 6 125 3 500 7 150	(a)+(b) 1s. 4d 33 cts.	½	About 1 000 000 gal. of sewage raised 84 ft. 250 000 gal., 35 ft. 250 000 gal., 25 ft. No ventilators in roof. Hopper storage of refuse.....	Front-feeding and stoking. Light and air at front of furnaces ample...	Clinkering hot work. Ample room. Clinker hard.....	Plant well operated. Some dust about building due to clinkering and dumping of refuse into hopper.	1 800 +	Sold for 1s. 8d. (41c.) per ton at the works. Revenue from clinker in 1905, £101 ($495)..	.....	Sold. Revenue, 1905, £8 ($39).	1.56 lb. in 9-hr. test on April 22, 1904 ..	None .
5 005 4 524 ling ed ay.)	(a) 1s. 25 cts.	¾	Cart storage of refuse a feature. Power used for lighting works and corporation yard, driving fan and supplying steam to disinfecting station.....	Stoking from rear of cell. Lack of light and air in stoking and clinkering level.....	Clinkering hot work. Space contracted; lack of air. Clinker hard.....	Interior of building rather dark and dusty. Smoke issuing from feeding doors when charging.....	1 600	Sold at 1s. 9d. (43 cts.) per ton	Used for setting stone pavements. Made into carbolic disinfecting powder.....	Sold	1.24 lb. for 6-day test.	None .
.....	.....	.....	This old type of furnace had been in operation for twenty years.....	Top-feeding; stoking at ground level....	Clinkered from front at ground level....	This old type of destructor would probably destroy without nuisance the refuse in sight.	.....	.....	.....	.....	.....	.....
10 241 50 181	(a) 1s. 1½d 28 cts. (e) 5%	1	Induced fan for additional draft.....	Stoking space lacks light and air. Hot work.....	Clinkering area restricted; firemen work under difficulties.....	Smoke escaped in large quantities from feeding ports when charging.....	1 800	Clinker fair in quality. Used for mortar making or barged away.....	Made into carbolic disinfecting powder....	.....	.....	Smok build feed are

uilders or operators of lestructors.			Operation of Plant—Observations.				Utilization of By-Products.				
ost of operation per long ton of refuse burned. a) Labor. b) Supervision. c) Interest. d) Sinking Fund. e) Repairs. f) Total.	Refuse burned per man per hour. Long tons (2 240 lb.)	Special notes on plant.	Feeding—Stoking.	Clinkering—Character of clinker.	General notes.	Approximate temperature of main flue at time of visit, in degrees, Fahrenheit.	Clinker.	Flue dust.	Tins, etc.	Reported evaporation per pound of refuse, from and at 212° fahr.	Nuisances possible ca of compla
Year 1902.											
(a) 1s. 6.88d 38.7 cts. (b) 1.44d 2.88 cts. (e) 2.02d 4.04 cts.	1+	Clinker utilization plant cost £750 ($3 675). Refuse carries day load of lighting station.....	Top-feeding from storage hopper. Stoking through clinkering doors...	Clinkering hot, heavy work. Clinker hard. Some smoke from clinker doors.	Interior of building dusty, from dumping into hoppers and clinkering. Clinker yard very dusty—wind blowing dust about.	1 800	Crushed, screened, and made into slabs or bricks. Sold at 1s. 6d. (37 cts.) per ton.....	.....	Sold.....	1.53 lb. during a run of 13 days in October, 1905	None.....
.....	1	Cremating chamber for dead animals, etc Water-sealed top-feeding doors. Cart storage of refuse.....	Direct-feeding from cart. Stoking from clinker doors.....	Clinkering hot work. Clinkers not very hard	Building clean and well kept. Plant working under easy conditions. Some dust while clinkering.....	1 800	Part sold, rest used for road bottoming, etc.....	.....	Sold.....	.....	None .....
(a) 1s. 1¾d 28½ cts.	¾	Repairs to plant under way when visited.....	Top-feeding through open ports. Smoke escaping through feed ports. Stoking through clinker doors.....	Clinkering difficult—poor air and light space. Clinker poor in quality....	Cramped working space at clinkering floor. Smoke and odors from clinker yard	Low—About 1 200 to 1 400	Carted off or made into mortar.....	.....	.....	.....	Odor from ker yard. temperatu
(a) 11d 22 cts. (e) No repairs.	½	No inclined roadway—carts dump on floor in rear of furnaces....	Front-feeding easily done. Good light and air for firemen.	Clinkering hot work. Clinker hard	Plant well operated. Very little dust about. Furnaces working under easy conditions. Storage of refuse on floor inadvisable.....	1 800	Hand-broken and used for mortar making and bacteria beds. Revenue, £180 ($911) per annum.....	.....	.....	.....	None.....
(a)+(b) 1s. 4d 33 cts.	½	About 1 000 000 gal. of sewage raised 84 ft. 250 000 gal., 35 ft. 250 000 gal., 25 ft. No ventilators in roof. Hopper storage of refuse.....	Front-feeding and stoking. Light and air at front of furnaces ample...	Clinkering hot work. Ample room. Clinker hard.....	Plant well operated. Some dust about building due to clinkering and dumping of refuse into hopper.	1 800 +	Sold for 1s. 8d. (41c.) per ton at the works. Revenue from clinker in 1905, £101 ($495)..	.....	Sold. Revenue, 1905, £8 ($39).	1.56 lb. in 9-hr. test on April 22, 1904 ..	None .....
(a) 1s. 25 cts.	¾	Cart storage of refuse a feature. Power used for lighting works and corporation yard, driving fan and supplying steam to disinfecting station.....	Stoking from rear of cell. Lack of light and air in stoking and clinkering level.....	Clinkering hot work. Space contracted; lack of air. Clinker hard.....	Interior of building rather dark and dusty. Smoke issuing from feeding doors when charging.....	1 600	Sold at 1s. 9d. (43 cts.) per ton.....	Used for setting stone pavements. Made into carbolic disinfecting powder.....	Sold	1.24 lb. for 6-day test.	None .....
.....	.....	This old type of furnace had been in operation for twenty years.....	Top-feeding; stoking at ground level....	Clinkered from front at ground level....	This old type of destructor would probably destroy without nuisance the refuse in sight.	.....	.....	.....	.....	.....	.....
(a) 1s. 1½d 28 cts. (e) 5%	1	Induced fan for additional draft.....	Stoking space lacks light and air. Hot work.....	Clinkering area restricted; firemen work under difficulties.....	Smoke escaped in large quantities from feeding ports when charging.....	1 800	Clinker fair in quality. Used for mortar making or barged away.....	Made into carbolic disinfecting powder....	.....	.....	Smoke building w feeding d are opene

Deductions.			
Nuisances or possible causes of complaint.	Objectionable features.	Commendable features.	Remarks.
None.	Dust inside building and in clinker yard. Some smoke in building.	Large plant, solidly built, well operated. Good power production. By-products utilized	Destructor portion fitted into general design made by consulting engineer.
None	Dust inside plant and in clinker yard. Small amount of smoke from feeding doors when charging.	Well-designed, constructed and operated plant. Light and ventilation excellent. Working under easy conditions.	Authorities required that no refuse should be handled.
Odor from clinker yard. Low temperature.	Dust in and around building. Top-feeding imperfect. Cramped working space and lack of light and air at clinkering floor.	Well-constructed buildings. Furnaces 11 years in operation. Older type of plant, but still doing fair work in disposing of refuse.	Repairs under way caused plant to be inspected under worst conditions.
None.	Open storage of refuse on floor in rear of furnaces not desirable.	Clean plant, well designed, constructed and operated. Working under easy and comfortable conditions. Saves a fuel bill of £370 ($1 813) per annum.	No inclined roadway provided because of considerations of cost.
None	Dust inside building and about clinker yard.	Saves a fuel bill of about £900 ($4 410) per annum. Plant well designed, constructed and operated	
None	Dust and smoke inside building. Stoking and clinkering space badly arranged.	Plant well operated, substantially constructed. Working under easy conditions.	
	Obsolete type of destructor.	Furnace twenty years in operation	
Smoke from building when feeding doors are opened.	Restricted site. Stoking and clinkering performed under difficulties.	High temperature. Furnaces well built	Destructor was required by the authorities to fit a very restricted site.

and compared with other plants visited. The facts secured at the different destructors were checked by comparison with published data where such were available.

Table 10 represents in condensed form the results of the writer's observations on the forty destructors examined. In summarizing and discussing British practice in refuse collection and destruction, the general order of the headings in Table 10 will be followed.

The Collection of Refuse.—British household refuse, consisting of ashes, garbage, and rubbish, is thrown into one can, bin, or ash-pit by the householder. The materials are then dumped or shoveled into a wagon or cart and removed to the place of final disposition. Organic waste (garbage) is not separated from ashes and rubbish, as is usually the practice in the large cities of the United States, where the reduction system has been generally adopted.

Municipal ownership and operation of the refuse-collection service in Great Britain is general, and the contract system is almost unknown. Single-horse covered wagons or vans, holding about 3 cu. yd. of material, are common in the larger cities, and the type of horse used is rather superior to any noticed in the vicinity of New York, on similar work.

Frequency of Collection.—Refuse is collected weekly in Great Britain, as a rule, though in some municipalities the material is removed daily, while in other cities, where the old-style ash-pit system is in use, a monthly clean-out is common. To an American acquainted with the daily collection of garbage in the large cities of the United States, this delay in removal may seem to be unsanitary, especially in summer, when organic wastes decompose rapidly, but differences in conditions explain the matter:

First.—Ashes, garbage and rubbish are thrown together into one receptacle, and the ashes absorb the excess of water and tend to deodorize or retard the decomposition of the garbage.

Second.—The average Briton is not as wasteful as the average inhabitant of Richmond Borough, as the figures in Table 11 indicate.

Thus the period during which the ordinary refuse receptacle overflows will be longer in Great Britain than in the West New Brighton District, for which accurate figures have been compiled.

Third.—Differences in climate and in the habits of the people may explain further the long-time period of refuse collection practiced in Great Britain.

TABLE 11.

Locality.	Tons (of 2 000 lb.) per 1 000 inhabitants per day.	Authority.
Average, England	0.83	George Watson.
South of England	0.56 to 0.84	H. N. Leask.
Middle England	1.12	H. N. Leask.
Northeastern England	2.24	H. N. Leask.
Tottenham, England	0.63	J. E. Butler-Hogan, M. D.
Bradford, England	1.176	Ernest Call.
Glasgow, Scotland	0.86	D. McColl.
Dublin, Ireland	0.836	F. J. Allen.
Richmond Borough, N. Y.		
Average	1.59	Author.
Maximum (winter-spring)	1.94	Author.
Minimum (summer)	1.18	Author.

The Cost of Collection.—English municipalities generally have excellent accounting systems, but poor cost-keeping methods, though in some cases both accounting and cost-keeping are in advance of most American cities.

Figures on the cost of collection of refuse (which includes removal to the place of final disposition) were available at four places, as follows:

Tottenham, England	$0.56	per ton of 2 000 lb.
Swansea, Wales (about)	0.67	" " " " "
Glasgow, Scotland (one year)	0.63	" " " " "
Bradford, England (one year)	0.68	" " " " "
Average	$0.635	" " " " "

In a later paragraph, the average labor cost for destroying mixed refuse in some British destructors is shown to be $0.215, hence the cost of collecting the material is about three times the cost of destroying it, when operating expenses alone are considered. Thus, in any system of final disposition of refuse, the cost of collection becomes a most important factor in the economy of the method.

Composition of Refuse.—The word refuse, used in this portion of the paper, refers to household refuse alone, as street sweepings were not burned at any of the plants visited. In some special cases, however, night-soil and dead animals were cremated at the destructors.

Household refuse will vary in composition according to:

(a).—The geographical position of the city and its relation to the fuel and food supply;

Reference Number.	Date visited; municipality; population; and area.	General character of population.	Collection of refuse.		Opinion on Character of Refuse.					Location of plant.	Type and description.	Erected.	Rated capacity, in tons (2 240 lb.) per 24 hours.	Appurtenances.
					Estimated composition by weight.				Apparent value as a fuel.					
			Frequency	Cost per long ton.	Ashes.	Garbage.	Rubbish.	Glass, metal, etc.	Note.—British refuse is dark brown to black in color—due to ash from bituminous coal.					
					%	%	%	%						
9	May 9, 1906; Finsbury Borough, London, Eng.; Pop., 98 958; Area, 589 acres.	Business and tenement; crowded district.	.....	.....	..	..	..	..	Refuse sorted by forking over; only rubbish and garbage burned. Ashes, bottles, etc., sold.....	Central. At Phoenix Wharf on banks of Thames.....	*Bakers.* Top-feed, 2 cells, 1 Hornsby boiler, induced fan draft.....	1899	15	Cells are separated. three working levels stoking and clinkering slides down an incline from rear and clinker at lowest level.....
10	May 10, 1906; Woolwich Borough, London, Eng.; Plumstead Destructor; Pop., 125 791, 86 000 in destructor district; Area, 8 986 acres	Suburban.	.....	.....	40	30	20	10	Fair. Moist refuse in sight—at least 30% water.....	Isolated. Row of houses 300 ft. off on one side.	*Meldrum.* Front hand-feed, 3 units of 4 grates, 3 B. & W. boilers, steam-jet blowers, heated air, superheaters, economizer.....	1903	80	Chimney of brick, 80 Brick buildings, elec tion in adjoining Supplementary coal-f plant. Not enough re able to run furnace capacity.....
11	May 11, 1906; Shoreditch Borough, London, Eng.; Pop., 118 705; Area, 640 acres.	Business and tenement.	.....	.....	60	20	15	5	Fair. Well mixed.....	Critical. Surrounded on all sides by buildings.	*Fryer's Improved.* Top-feed, patent charging device, 12 cells, back to back, 6 B. & W. boilers, fan draft, cold air, economizer, chimney 150 ft. high.....	1897	100	Boulnois, Wood & Brod charging trucks in us arranged for coal firin elevated to top of f power, then dropped ing trucks. Therm system in use.....
12	May 11, 1906; Bermondsey Borough, London, Eng.; Bermondsey Destructor; Pop., 130 486; Area, 1 506 acres.	Poor people generally.	.....	.....	60	30	6	4	Fair. Calorific value said to be 15% higher in winter than in summer.....	Critical. In rear of Town Hall, with houses on all sides. Corporation yard.....	*Sterling.* Top-feed, 8 cells, 4 B. & W. boilers, fan draft with cold air, brick chimney 150 ft. high.....	1902	80	Refuse stored on top of for forced draft dr hood under which cooled by a spray of w any obnoxious odors from the cooling re passed back through
13	May 12, 1906; East Ham. Municipal Corporation, Eng.; Pop., 120 000; Area, 3 320 acres.	Suburban; poor people generally.	.....	.....	60	20	10	10	Fair.....	Isolated. At sewage farm.....	*Meldrum.* 2 4-grate units, 1 in operation, 1 under construction, 2 boilers, steam-jet blowers, heated air.....	1904 1906	30 for 1 unit.	New furnace very su constructed. The u ation is doing excell Building is large, wit light and air; glazed on interior walls.....
14	May 14, 1906; Sheerness Urban District Council, Eng.; Pop., 20 000; Area, ...	Poor people mainly; government dockyards.	.....	.....	40	30	20	10	Rather poor in quality. Large quantity of garden refuse....	Critical. Houses on all sides. School about 8 ft. from refuse storage room.....	*Meldrum.* 1 unit of 2 grates, front hand-feed, steam-jet blowers, heated air, 1 Lancashire boiler, chimney 90 ft. high.....	1903	24	Separate room for ti storage of refuse. mental coal-fired boi use when destruct working .....
15	May 14, 1906; Chatham Dockyard, Eng.; Pop., 15 000; Area., ...	Naval and military post.	.....	.....	..	..	..	..	No refuse in sight. Said to be of high calorific quality....	Central. Inside main gateway of dockyard	*Meldrum.* 1 unit of 4 grates, front hand-feed, steam-jet blowers, heated air, 1 Lancashire boiler.....	1906	50 to 60	Very substantial Building open in fr age hopper. Lar power station next
16	May 15, 1906; Walthamstow Urban District Council, Eng.; Pop., 115 000; Area, 4 355 acres.	Mixed; large number of poor people, stores, business, etc.	Bi-weekly...	.....	35	35	25	5	Rather poor in quality.	At sewage farm and corporation yard. Workmen's houses 100 ft. away on one side.....	*Meldrum.* 2 units of 4 grates each, 2 Lancashire boilers, steam-jet blowers, heated air, fitted for top-feeding or front hand-feeding, latter now in use.....	1905	100 tons for both units; 40 tons now burned in one unit.	Dead animals cremate bustion chamber o Designed for top-f sewage sludge, but t of sludge was di Brick chimney 120 Corrugated iron bui

TABLE 10 (*Continued*).—REFUSE DESTRUCTORS VISITED IN ENGLAND, WALES, IRELAND, SCOTLAND AND

DATA ON PLANT.										
Type and description.	Erected.	Rated capacity, in tons (2 240 lb.) per 24 hours.	Appurtenances.	Power utilized for:	Data from builders or operators of destructors.			Special notes on plant.	Feeding—
					Cost of construction: (a) Complete. (b) Building. (c) Chimney. (d) Destructor, with boiler and accessories.	Cost of operation per long ton of refuse burned. (a) Labor. (b) Supervision. (c) Interest. (d) Sinking Fund. (e) Repairs (f) Total.	Refuse burned per man per hour. Long tons (2 240 lb.)		
...kers. Top-feed, 2 cells, 1 Hornsby boiler, induced fan draft.....	1899	15	Cells are separated. There are three working levels—feeding, stoking and clinkering. Refuse slides down an incline, is stoked from rear and clinkered in front at lowest level.....	Fan engine only.....	.....	.....	.....	Cells placed in a restricted site.....	Stoking Air and li badly arr
...eldrum. Front hand-feed, 3 units of 4 grates, 3 B. & W. boilers, steam-jet blowers, heated air, superheaters, economizer.....	1903	80	Chimney of brick, 80 ft. high. Brick buildings, electrical station in adjoining building. Supplementary coal-fired boiler plant. Not enough refuse available to run furnaces at full capacity.....	Electric lighting and works purposes.....	.....	.....	⅔	Large modern installation. Complete clinker utilization plant for making bricks and slabs.....	Front-feedi stoking. heavy wo
...ryer's Improved. Top-feed, patent charging device, 12 cells, back to back, 6 B. & W. boilers, fan draft, cold air, economizer, chimney 150 ft. high.....	1897	100	Boulnois, Wood & Brodie's patent charging trucks in use. Boilers arranged for coal firing. Refuse elevated to top of furnace by power, then dropped into charging trucks. Thermal storage system in use.....	Electric lighting and works purposes.....	(a) £20 527 ($100 582)	(a) 1s. 10.14d. (45.3 cts.) (b) 4.12d. (8¼c). (c) 7.6d., including maintenance and stores (1903). (7.6d.=15.4 cts.)	.....	Ambitious scheme for utilizing power from refuse. Economizer being repaired at time of visit.....	Front-stokin work.....
...erling. Top-feed, 8 cells, 4 B. & W. boilers, fan draft with cold air, brick chimney 150 ft. high.....	1902	80	Refuse stored on top of cells. Air for forced draft drawn from hood under which clinker is cooled by a spray of water, thus any obnoxious odors resulting from the cooling residue are passed back through the cells..	Electric power and steam for public baths.....	.....	.....	.....	Brickwork and ironwork of cells in bad state of repair. Plenty of light and air in building. Supplemental coal-fired boiler plant.....	Front-stokin clinker flo
...eldrum. 2 4-grate units, 1 in operation, 1 under construction, 2 boilers, steam-jet blowers, heated air.....	1904 1906	30 for 1 unit.	New furnace very substantially constructed. The unit in operation is doing excellent work. Building is large, with plenty of light and air; glazed brick used on interior walls.....	Sewage pumping and works purposes.....	(a) £12 600 ($61 740)	(a) 1s. 7d. (39 cts.)	.....	3 250 090 gal. of sewage pumped per day. Average lift 26 ft. Centrifugal pumps...	Feeding, s and clin from fron
...eldrum. 1 unit of 2 grates, front hand-feed, steam-jet blowers, heated air, 1 Lancashire boiler, chimney 90 ft. high.....	1903	24	Separate room for tipping and storage of refuse. Supplemental coal-fired boiler plant in use when destructor is not working.....	Water pumping.....	(a) £3 500 ($17 150) (d) £2 420 ($11 858)	(a) 1s. (25 cts.)	.....	Destructor not in operation when visited. Men cleaning out flues.....	All work front of fu
...eldrum. 1 unit of 4 grates, front hand-feed, steam-jet blowers, heated air, 1 Lancashire boiler.....	1906	50 to 60	Very substantial destructor. Building open in front. Storage hopper. Large central power station next door.....	Electric power.....	(d) £3 500 ($17 150)	.....	.....	Destructor just finished.	All work front of fu
...eldrum. 2 units of 4 grates each, 2 Lancashire boilers, steam-jet blowers, heated air, fitted for top-feeding or front hand-feeding, latter now in use.....	1905	100 tons for both units; 40 tons now burned in one unit.	Dead animals cremated in combustion chamber of furnace. Designed for top-feeding of sewage sludge, but the burning of sludge was discontinued. Brick chimney 120 ft. high, Corrugated iron building.....	Sewage pumping and works purposes.....	(a) £10 000 ($49 000)	(a) 1s. (25 cts.)	½	Pumping plant in an adjoining building. Steam blowing off at 120-lb. pressure at time of visit.....	All work front of Clinkering dusty wor

Operation of Plant—Observations.				Utilization of By-Products.				Deduct
ing—Stoking.	Clinkering—Character of clinker.	General notes.	Approximate temperature of main flue at time of visit, in degrees, Fahrenheit.	Clinker.	Flue dust.	Tins, etc.	Reported evaporation per pound of refuse, from and at 212° fahr.	Nuisances or possible causes of complaint.	Objectionable fea
ng difficult. and light very y arranged...	Clinkering difficult, clinker not completely burned....	Fire in cells dull. Temperature low. Smoke from feeding doors.....	1 200	Poor in quality; not completely burned.....	.....	Sold.....	.....	Smoke. Low temperature..	Plant badly loc Defective in des
feeding and ing. Hot and y work.....	Clinker fair. Clinker removal by barrows is hot work..	Well-designed, constructed and operated plant. Plenty of light and air in building. Dust from clinkering and flue cleaning.....	1 800+	Clinker about 30% of original refuse. Clinker made into slabs, bricks, mortar, or used for road bottoming...	.....	.....	1 917 lb. in 24-hr. test.	None.....	Dust inside bui and in clinker Clinkering very h work. Plant a ently too large present requ ments.....
stoking; hot r.....	Clinker poor in quality; some unburned particles in residue.....	Air in building dusty; smoke escaping from top-feeding doors; odors about plant.....	1 500	Carted off; not utilized.....	Sold.....	.....	.....	Smoke from top-feeding doors; odors from clinker.....	Plant badly locate crowded section; plicated feedin vice; lack of and air in buildi
stoking from ker floor.....	Clinker fair in quality. Clinkering heavy, hot work...	Open top-feeding ports covered by refuse; dust arises when tipping refuse on top of cells. Storage system for refuse defective in design.....	1 800	Carted off; not utilized.....	Carted away.....	.....	.....	None.....	Top-feeding and r storage system fective; cells in state of repair; inside building...
ng, stoking clinkering n front.....	Clinker hard. Hot work removing clinker by barrow.	Plant working under easy conditions.....	1 800+	Sold at 1s. (25 cts.) per ton.....	.....	.....	.....	None.....	Dust from storage per and from c ering operations
work done at t of furnace...	Clinker in sight, hard, well burned.	Buildings clean and well kept; destructor in good repair.....	Furnace not in operation.....	Sold or made into mortar or hand-made slabs.....	Carbolic powder base	.....	.....	None.....	Dust from refuse clinker.....
work done at t of furnace...	Clinker removal space rather badly arranged.....	.....	Not in operation.....	.....	.....	.....	.....	None likely.....	Possibility of dust tipping of refuse clinkering, ca some local dis fort.....
work done at t of furnace. kering hot, ty work.....	Clinker hard, well burned	Plant well managed and well operated; power used for various purposes about Corporation yard..	2 000	Sold at 6d. (12 cts.) per load, or made into slabs	Used as a base for carbolic powder.....	Sold at 17s. 6d. ($4.37) per ton.	.....	None.....	Dust from storage per and from cli ing operations..

s.		Utilization of By-Products.				
l notes.	Approximate temperature of main flue at time of visit, in degrees, Fahrenheit.	Clinker.	Flue dust.	Tins, etc.	Reported evaporation per pound of refuse, from and at 212° fahr.	Nuisances possible ca of compla
ull. Tempera- Smoke from rs.....	1 200	Poor in quality; not completely burned.....	.....	Sold.....	.....	Smoke. temperatu
l, constructed rated plant. ght and air in Dust from nd flue clean-	1 800+	Clinker about 30% of original refuse. Clinker made into slabs, bricks, mortar, or used for road bottoming...	.....	.....	1 917 lb. in 24-hr. test.	None.....
ding dusty; oing from top- ors; odors	1 500	Carted off; not utilized.....	Sold.....	.....	.....	Smoke from feeding d odors clinker...
ing ports cov- refuse; dust n tipping top of cells. tem for refuse design.....	1 800	Carted off; not utilized.....	Carted away.....	.....	.....	None.....
g under easy	1 800+	Sold at 1s. (25 cts.) per ton.....	.....	.....	.....	None.....
an and well uctor in good	Furnace not in operation.....	Sold or made into mortar or hand-made slabs.....	Carbolic powder base	.....	.....	None.....
.....	Not in operation.....	.....	.....	.....	.....	None likely
managed and ted; power ious purposes oration yard..	2 000	Sold at 6d. (12 cts.) per load, or made into slabs	Used as a base for carbolic powder.....	Sold at 17s. 6d. ($4.37) per ton.	.....	None.....

	Deductions.			
	Nuisances or possible causes of complaint.	Objectionable features.	Commendable features.	Remarks.
	Smoke. Low temperature..	Plant badly located. Defective in design..	.....	
est.	None.....	Dust inside building and in clinker yard. Clinkering very heavy work. Plant apparently too large for present requirements.....	Excellent plant. High temperatures. Steady steaming. Clinker utilized.....	
	Smoke from top-feeding doors; odors from clinker.....	Plant badly located in a crowded section; complicated feeding device; lack of light and air in building ...	Plant well operated; very complete records of costs available.....	It should be noted that the repairs under way at time of visit might cause some of the objectionable features.
.....	None.....	Top-feeding and refuse storage system defective; cells in poor state of repair; dust inside building.....	Plant well managed; developing 63 electrical units per ton of refuse burned.....	
.....	None.....	Dust from storage hopper and from clinkering operations.....	Substantial plant, doing excellent work; said to save £1 000 ($4 900) per annum in coal bills.....	
.....	None.....	Dust from refuse and clinker.....	Excellent plant; well managed; central location; refuse tipped and stored in separate building. Saves £400 ($1 960) net in fuel bills.....	
.....	None likely.....	Possibility of dust from tipping of refuse and clinkering, causing some local discomfort.....	Well-constructed plant, of modern design.....	
.....	None.....	Dust from storage hopper and from clinkering operations.....	Furnaces duplicated to avoid complete shutdown for cleaning; clinker well utilized. Saves in fuel £650 ($3 185) per annum.....	

(b).—The particular district of the city considered, as business, residential, tenement, or manufacturing;

(c).—The character and habits of the people;

(d).—The season of the year.

Very little attention has been given by municipal engineers to determining the composition and calorific value of British refuse, and so only scattered data are available for comparison with the refuse of other countries. British destructor makers, however, base their guaranties of power production upon an examination of the refuse in each locality. This involves a previous experience with results obtained under like conditions at other places. Thus a sight valuation or estimate of the composition of refuse in different cities should be of service in determining the feasibility of burning refuse without the use of additional fuel, and for comparing results in power production.

At each plant an estimate, by weight, was made of four general components of refuse, *viz.:* (1) ashes, including other small inorganic materials; (2) garbage, or organic matter; (3) rubbish, or paper, straw and such light combustible materials; and (4) glass, metal, etc. Some previous experience helped the writer in this respect, though it should be understood that the figures for the different cities shown in Table 10 are based upon the quantity of refuse on hand when each plant was visited, and are merely rough estimates.

At first sight, the difference in general appearance of British refuse and that found in the vicinity of New York was apparent. The color of British refuse is dark brown to black, due to the soft coal ashes, while ashes from hard coal, such as used in New York, are light gray in color. Again, British refuse varies in appearance and composition with the distance from the coal fields, the character of the district, and the habits of the people. In London and the south of England, the refuse is rather lighter in color than that found in Middle England in or near the colliery districts, where it is darker, and more unconsumed lump coal is visible.

In comparing American household refuse with the estimates given in Table 10, localities having the same general characteristics and for the same period of the year should be chosen. On this basis, as a general conclusion, the writer is of the opinion that British refuse

contains more ashes, less garbage, less rubbish and more moisture than household refuse in the vicinity of New York, though the higher percentage of moisture during May and June, 1906, might have been due to a prolonged rainy period. From such information as was obtainable regarding the composition of British refuse, it would appear that no such seasonal variations occur as may be found in comparing American summer with American winter refuse, while, during the fruit season, British refuse contains no wastes comparable to melon rinds and corn cobs.

A superficial observation of British refuse is apt to prove deceptive in the amount of garbage present in the mixed mass, as the dark ash tends to cover and conceal garbage which would otherwise be quite apparent in the lighter colored anthracite ash.

Apparent Value as a Fuel.—That British refuse has a fuel value is proved beyond a doubt by the two hundred or more destructors in which refuse is burned throughout the year without additional fuel. There would seem to be no large seasonal variation in the calorific power of the material, though in one instance a difference in steam production of 15% less in summer than in winter has been noted.

The average evaporation for eighteen tests quoted in Table 10 amounts to 1.62 lb. of water per pound of refuse. Assuming an efficiency of 50% (boiler and grate) per pound of refuse, the calorific value of the average material burned during the tests would amount to 3 130 B. t. u., which practically agrees with the estimated calorific power of average British refuse given by various authorities on the subject.

Location of Plants.—The location of a plant for the final disposition of refuse has a most important bearing on the cost of the collection (including removal) of the material. Economy in collection requires that the plant shall be centrally located with regard to the district served, and that loaded collection wagons or carts shall proceed with the road gradient.

Of the forty destructors, four were critically located, so that the least nuisance would probably result in the abandonment of the plants; seventeen were centrally located in advantageous positions with regard to the district served, but the surrounding houses were not in close proximity to the destructors; nineteen were placed on the outskirts of towns and not likely to cause complaint, even if the plants were not well operated.

Reference Number.	Date visited; municipality; population; and area.	General character of population.	Collection of refuse.		Opinion on Character of Refuse.					Location of plant.	Type and description.	Erected.	Rated capacity, in tons (2 240 lb.) per 24 hours.	Appu
			Frequency.	Cost per long ton.	Estimated composition by weight. Ashes.	Garbage.	Rubbish.	Glass, metal, etc.	Apparent value as a fuel. Note.—British refuse is dark brown to black in color—due to ash from bituminous coal.					
					%	%	%	%						
17	May 15, 1906; Tottenham Urban District Council, Eng.; Pop., 122 000; Area, 3 033 acres.	Mixed.....	Weekly...	2s. 6d., or about 62½c.	..	..	.....	.....	No refuse in sight. Said to be of poor quality.	Isolated. On outskirts of town.....	*Warner.* Top-feed, single row, 10 cells, fan draft (cold air), 5 multitubular boilers, economizer, brick chimney 180 ft. high.....	1903	80	There are 10 c with one boi cell has a sep draft. Clin overhead ra cars or by l softening pl
18	May 16, 1906; Kettering Urban District Council, Eng.; Pop., 31 000; Area, 2 814 acres.	Working people, stores, residences, manufactories, boot and shoe making centre.	Weekly.....	.....	50	30	10	10	Fair. Destructor builder guaranteed 1.2 lb. steam per lb. refuse.	Central. Surrounded by workmen's houses.	*Meldrum.* One 2-grate unit, Lancashire boiler, steam-jet blowers, heated air, front hand-feed, economizer, by-pass flue to chimney.....	1904	25	Large electri adjoining pl tion about the destruct Coal-fired l mainder of
19	May 17, 1906; Stoke-upon-Trent Municipal Corporation, Eng.; Pop., 33 000; Area, 1 881.	Laboring people generally; colliery and pottery district.	Weekly.....	.....	..	..	..	..	Good. Mainly ashes with some lump coal showing.....	Central. Row of workmen's houses about 100 ft. away.....	*Meldrum.* Front hand-feed, 2 units of 3 grates each, 2 Lancashire boilers, steam-jet blowers, heated air, economizer, cremating chambers, chimney 120 ft.....	1903	30	Destructor in in reserve. iliary plant, all power. buildings. plant in op
20	May 17, 1906; Burslem Municipal Corporation, Eng.; Pop., 52 424; Area, 4 202 acres.	Laboring people generally; colliery and pottery district.	.....	.....	....	..	..	..	Good. Same as at Stoke, except that there was more moisture apparent.	Isolated. Nearest house 600 ft. away	*Heenan.* Single unit of 3 grates, front hand-feed, B. & W. boiler, fan draft, heated air. Same general type as the Meldrum.....	1905	30	Supplementa use when down, other all power us helps carry
21	May 18, 1906; Swansea (Wales) Municipal Corporation; Pop., 94 514; Destructor serves 50 000; Area, 6 229 acres.	Mixed. Colliery district.	Daily to fortnightly.	About 3s.(75c.) per ton.	75	15	5	5	Good. Some unburned lump coal visible	Central. Hills on two sides with workmen's houses, a school and a church higher than chimney top.....	*Horsfall.* 5 cells, single row, back hand-feed, 1 Lancashire boiler, steam-jet blowers, heated air, chimney 120 ft. high. Boiler fitted for coal firing.....	1904	64	Native stone for storage crushing a cost £910 ($
22	May 19, 1906; Wrexham (Wales) Municipal Corporation; Pop., 14 966; Area, 1 305 acres.	Laboring people generally; colliery employees. Coal district.	Weekly.....	.....	....	..	..	..	Said to be good. Refuse in sight consisted mainly of rubbish from stores.	Critical. Houses on all sides, 1 house 30 ft. from hopper. Corporation yard	*Meldrum.* 1 unit of 4 grates, front hand-feed, 1 Lancashire boiler, steam-jet blowers, heated air. Chimney 120 ft. high.....	1900	48 Burns about 30	Supplementa plant carrie adjoining el Chimney v and coal-fir
23	May 19, 1906; Llandudno (Wales) Urban District Council; Pop., Resident, 9 310; Pop., Summer, 30 000; Area, 2 892 acres.	Summer resort. Large number of hotels and boarding houses.	.....	.....	....	..	..	..	Refuse in sight mainly rubbish and garbage; see Fig. 3, Plate XCVI. At times coal is used with refuse to keep up the temperature.	Isolated. On outskirts of town, adjoining electric-lighting station and gas plant.....	*Meldrum, Beaman & Deas.* 2 units of 2 cells each, back to back, top-feed, 2 B. & W. boilers, fan draft (cold air), economizer.....	1898	25	Coal-fired boi tion in same Generator building. from 8 P. each day..
24	May 21, 1906; Dublin (Ireland); Pop., 263 000; Area, ...	Business and residential. Large poor quarter.	Daily for 65% and tri-weekly for 35% of houses....	.....	65	25	8	2	Fair. Refuse in sight came mainly from a tenement house section.....	Central. At an old manure station where a Fryer destructor formerly was operated.	*Meldrum.* 2 units of 4 grates each, back hand-feed, 2 B. & W. boilers, steam-jet blowers, heated air. Old chimney 125 ft. high. Open refuse storage bin.....	1906	120	Destructor h ing next cell Fry furnace. mortar-ma machinery

TABLE 10 (*Continued*).—REFUSE DESTRUCTORS VISITED IN ENGLAND, WALES, IRELAND, SCOTLAND AND CANADA.

DATA ON PLANT.										
nd description.	Erected.	Rated capacity, in tons (2 240 lb.) per 24 hours.	Appurtenances.	Power utilized for:	Data from builders or operators of destructors. Cost of construction: (a) Complete. (b) Building. (c) Chimney. (d) Destructor, with boiler and accessories.	Cost of operation per long ton of refuse burned. (a) Labor. (b) Supervision. (c) Interest. (d) Sinking Fund. (e) Repairs. (f) Total.	Refuse burned per man per hour. Long tons (2 240 lb.)	Special notes on plant.	Feeding—Stoking.	
Top-feed, single row, fan draft (cold ultitubular boilers, er, brick chimney gh.....	1903	80	There are 10 cells in a single row with one boiler to 2 cells. Each cell has a separate fan for forced draft. Clinker is removed by overhead rail, by narrow-gauge cars or by barrows. A water-softening plant is in use.....	Works purposes. Driving fans and crushing clinker.....	.....	.....	.....	Excellent inclined roadway, building and chimney. Plant intended to provide power for electric lighting, but project abandoned.....	Top-feeding arrangement defective; smoke escaping from doors....	S
One 2-grate unit, re boiler, steam-jet heated air, front l, economizer, by-to chimney.....	1904	25	Large electric-lighting station adjoining plant. Output of station about 230 kw., of which the destructor furnishes 50 kw. Coal-fired boilers furnish remainder of power.....	Electric lighting.....	(a) £5 200 $25 480 (d) £2 843 $13 931	(a) From 10d. (20 cts.) to 1s. 1d. (27 cts.)	½	Well-constructed plant. General design made by a consulting engineer.....	All work done at front of furnace. Lack of light and air apparent.....	
Front hand-feed, 2 3 grates each, 2 re boilers, steam-jet heated air, econo-emating chambers, 120 ft.....	1903	30	Destructor in duplicate; 1 unit in reserve. No coal-fired auxiliary plant. Refuse furnishes all power. Substantial brick buildings. Water softening plant in operation.....	Electric lighting.....	£14 350 $70 375 (complete plant, including electrical installation.)	(f) 4s. 8½d. ($1.17) (c) 1s. 3d. (31c.) (d) + depreciation 1s. 3d. (31c.) (e) 1.2d. (2.4c.)	4/10 complete year's figures.	Very complete installation. No coal used to help out on peak loads.....	Good light and air. Hopper between the two units.....	
ngle unit of 3 grates, nd-feed, B. & W. an draft, heated e general type as the	1905	30	Supplemental coal-fired boiler in use when destructor is shut down, otherwise refuse provides all power used. Storage battery helps carry the heavy loads....	Electric lighting.....	(a) £3 990 $18 951 (b) £1 200 $5 880 (d) £2 790 $13 671	(a) 9.5d. (19c.)	⅛	Furnace operated 16 hr. per day; shows signs of hard driving.	Rather cramped space; light and air lacking; dusty.	
5 cells, single row, l-feed, 1 Lancashire team-jet blowers, ir, chimney 120 ft. ler fitted for coal	1904	64	Native stone buildings. Open bin for storage of refuse. Clinker-crushing and screening plant cost £910 ($4 459).....	Electric power for 4½ miles of street railway.	(a) £11 000 $53 900 (d) £3 961 $19 409	(a) 8.4d. (17c.)	⅜	High pressure of forced draft causes flames to issue from stoking doors. Hard-driven incinerator.....	Feeding space cramped. Refuse too near stoking doors.....	
1 unit of 4 grates, l-feed, 1 Lancashire team-jet blowers, r. Chimney 120 ft.	1900	48 Burns about 30	Supplemental coal-fired boiler plant carries most of the load in adjoining electric power station. Chimney used by destructor and coal-fired boilers.....	Electric lighting and traction. Heating baths and gymnasium.	(a) £2 311 $11 324 (d) £1 643 $8 051	(a) 1s. 2d. (29c.) (e) In 4 years the total cost of repairs was £21 ($103)	¾	Furnace operated 10 hr. per day. Flues well arranged for cleaning. Destructor worked continuously for 11 months.....	Feeding and stoking room lacks light and air.....	
Beaman & Deas. 2 cells each, back top-feed, 2 B. & W. fan draft (cold omizer.....	1898	25	Coal-fired boilers of electrical station in same room as destructor. Generator room in adjoining building. Destructor operated from 3 P. M. to about 11 P. M. each day.....	Electric lighting. About 100 h. p. available from destructor boilers.....	(a) £5 710 $27 979	(a) 1s. 3¼d. (31½ cts.)	About ¾	Destructor not working when visited.....	Top-feeding, rear stoking.....	
2 units of 4 grates k hand-feed, 2 B. boilers, steam-jet heated air. Old 125 ft. high. Open rage bin.....	1906	120	Destructor housed in an old building next to an abandoned 4-cell Fryer natural draft furnace. Clinker-crushing, mortar-making and tin-baling machinery provided.....	Works purposes.....	.....	.....	.....	Destructor just finished—not yet accepted. Not working when visited.....	Back hand-feeding. Open bin for storage of refuse objectionable.....	

OPERATION OF PLANT—OBSERVATIONS.				UTILIZATION OF BY-PRODUCTS.				DEDUCTIONS.		
	Clinkering—Character of clinker.	General notes.	Approximate temperature of main flue at time of visit, in degrees, Fahrenheit.	Clinker.	Flue dust.	Tins, etc.	Reported evaporation per pound of refuse, from and at 212° fahr.	Nuisances or possible causes of complaint.	Objectionable features.	Con
	Some unburned matter in clinker.....	Plant well operated; clean. Design defective.....	Low; about 1 400	Sold at 2s. (50c.) per ton.....	.....	Sold at 17s. 6d. ($4.37) per ton.	.....	Smoke from feeding doors; low temperature.....	Smoke; dust; low temperature.....	Amp go an cle
	Clinker hard, well burned. Clinkering hot work.....	Plant well operated	1 800	Used for making footpaths. Proposed use as bacteria beds	Proposed use as a base for carbolic powder..	Sold at 6d. (12c.) per ton.	1.48 lb. in 10½-hour test	None.....	Dust in and about building; feeding and clinkering space lacks light and air.....	Very ope ca ($1 ref
	Clinkering hot, heavy work. Clinker hard.....	Plant well managed and well operated; unit costs of all charges available ..	1 800+	Crushed, screened and sold or used for road bottoming.....	Used as a base for disinfectant.....	Sold at 5s. ($1.25) per ton.	2.66 lb. in 15-hour test	None.....	Dust in and about building.....	Dest pli co ava Pr to
	Clinkering hot, heavy work. Clinker hard.....	Power production for electric lighting the main object of this installation. Plant well operated to this end.....	1 800+	Used for filling adjacent ravine.....	Used for filling...	.....	2.16 lb. in 7¼-hour test.....	None.....	Dust inside building; Destructor being pushed too hard; probable short life, with high cost of repairs.....	High du of tro to tie
	Clinkering hot, heavy work. Clinker fair in quality, but not burned long enough to be very hard	Well-managed, well-operated plant. Cost of repairs probably high. Dust fusing in flues caused trouble.....	2 000	Made into mortar or clinker concrete and used for building sewers, retaining walls, etc., or dumped on adjoining fill.....	.....	To be baled and sold.	1.20 lb. in 23-hour test.....	None.....	Refuse storage system defective. Dust inside building. Cells being forced too much. Probable high cost of repairs.....	Hi Po ad ut pl
	Clinkering space lacks light and air	Destructor designed to furnish all power for electric generating station, but amount of refuse inadequate. Destructor not working when examined.	Not working when visited	Used for footpaths or for filling.....	Used for filling.	Carted off.	.....	None.....	Destructor building badly located. Dust in and about destructor. Feeding and clinkering room lacks light and air.....	Abil pe pi Lo Fa W op
	Clinkering from front of cells. Lack of light.....	Destructor not working.....	Not working	Sold at 6d. (12c.) per load.....	.....	Sold.....	.....	None.....	Top-feeding defective. Repairs high. Dust about building. Cold air for forced draft. Plant not of modern design	Disp ou to an W
	Front clinkering; ample light and air.....	Not working when visited....	.....	To be utilized.....	.....	To be baled in a press and sold.	.....	None probable..	Dust about building. Storage of refuse in open bin instead of hopper is objectionable.....	Wel wa pr be by ra st le

from builders or operators of destructors.			Special notes on plant.	Operation of Plant—Observations.				Utilization of By-Products.			Reported evaporation per pound of refuse, from and at 212° fahr.	Nu poss of c
on- n: ete. g. ey. ctor, and es.	Cost of operation per long ton of refuse burned. (a) Labor. (b) Supervision. (c) Interest. (d) Sinking Fund. (e) Repairs. (f) Total.	Refuse burned per man per hour. Long tons (2 240 lb.)		Feeding—Stoking.	Clinkering—Character of clinker.	General notes.	Approximate temperature of main flue at time of visit, in degrees, Fahrenheit.	Clinker.	Flue dust.	Tins, etc.		
....	.....	.....	Excellent inclined roadway, building and chimney. Plant intended to provide power for electric lighting, but project abandoned.....	Top-feeding arrangement defective; smoke escaping from doors....	Some unburned matter in clinker.....	Plant well operated; clean. Design defective.....	Low; about 1 400	Sold at 2s. (50c.) per ton.....	.....	Sold at 17s. 6d. ($4.37) per ton.	.....	Smo feed low ture
200 480 843 981	(a) From 10d. (20 cts.) to 1s. 1d. (27 cts.)	½	Well-constructed plant. General design made by a consulting engineer.....	All work done at front of furnace. Lack of light and air apparent	Clinker hard, well burned. Clinkering hot work.....	Plant well operated	1 800	Used for making footpaths. Proposed use in bacteria beds	Proposed use as a base for carbolic powder..	Sold at 6d. (12c.) per ton.	1.48 lb. in 10½-hour test	None.
350 375 ete id- eal n.)	(f) 4s. 8¼d. ($1.17) (c) 1s. 3d. (31c.) (d) + depreciation 1s. 3d. (31c.) (e) 1.2d. (2.4c.)	4/10 complete year's figures.	Very complete installation. No coal used to help out on peak loads.....	Good light and air. Hopper between the two units.....	Clinkering hot, heavy work. Clinker hard.....	Plant well managed and well operated; unit costs of all charges available ..	1 800+	Crushed, screened and sold or used for road bottoming.....	Used as a base for disinfectant.....	Sold at 5s. ($1.25) per ton.	2.66 lb. in 15-hour test	None.
090 951 200 880 790 371	(a) 9.5d. (19c.)	½	Furnace operated 16 hr. per day; shows signs of hard driving.	Rather cramped space; light and air lacking; dusty.	Clinkering hot, heavy work. Clinker hard.....	Power production for electric lighting the main object of this installation. Plant well operated to this end.....	1 800+	Used for filling adjacent ravine.....	Used for filling...	.....	2.16 lb. in 7¼-hour test.....	None.
000 900 961 409	(a) 8.4d. (17c.)	⅔	High pressure of forced draft causes flames to issue from stoking doors. Hard-driven incinerator.....	Feeding space cramped. Refuse too near stoking doors.....	Clinkering hot, heavy work. Clinker fair in quality, but not burned long enough to be very hard	Well-managed, well-operated plant. Cost of repairs probably high. Dust fusing in flues caused trouble.....	2 000	Made into mortar or clinker concrete and used for building sewers, retaining walls, etc., or dumped on adjoining fill.....	.....	To be baled and sold.	1.20 lb. in 23-hour test.....	None.
311 324 343 051	(a) 1s. 2d. (29c.) (e) In 4 years the total cost of repairs was £21 ($103)	¾	Furnace operated 10 hr. per day. Flues well arranged for cleaning. Destructor worked continuously for 11 months.....	Feeding and stoking room lacks light and air.....	Clinkering space lacks light and air	Destructor designed to furnish all power for electric generating station, but amount of refuse inadequate. Destructor not working when examined.	Not working when visited	Used for footpaths or for filling.....	Used for filling.	Carted off.	.....	None
710 079	(a) 1s. 3½d. (31½ cts.)	About ¾	Destructor not working when visited.....	Top-feeding, rear stoking.....	Clinkering from front of cells. Lack of light.....	Destructor not working.....	Not working	Sold at 6d. (12c.) per load.....	.....	Sold.....	.....	None
....	.....	.....	Destructor just finished —not yet accepted. Not working when visited	Back hand-feeding. Open bin for storage of refuse objectionable.....	Front clinkering; ample light and air.....	Not working when visited....	.....	To be utilized.....	.....	To be baled in a press and sold.	.....	None

vapora- pound rom and ahr.	Deductions.			Remarks.
	Nuisances or possible causes of complaint.	Objectionable features.	Commendable features.	
.....	Smoke from feeding doors; low temperature.....	Smoke; dust; low temperature.....	Ample room about plant; good building, roadway and chimney. Plant clean; well operated..	
0½-hour	None.....	Dust in and about building; feeding and clinkering space lacks light and air.....	Very good plant; well operated; centrally located. Saves £350 ($1 715) in haulage of refuse.....	Destructor was required to fit into general design of station.
15-hour	None.....	Dust in and about building.....	Destructor units in duplicate; no coal used; complete unit costs available (unusual). Produced 108 kw. per ton of refuse on test...	
7¼-hour	None.....	Dust inside building; Destructor being pushed too hard; probable short life, with high cost of repairs.....	High temperature; produces 100 kw. per ton of refuse without trouble. Power sold to adjacent municipalities.....	
23-hour	None.....	Refuse storage system defective. Dust inside building. Cells being forced too much. Probable high cost of repairs.....	High temperatures. Power utilized to good advantage. Clinker utilized. Well-operated plant.....	
.....	None.....	Destructor building badly located. Dust in and about destructor. Feeding and clinkering room lacks light and air.....	Ability to run for long periods without stopping for cleaning flues. Low cost of repairs. Fair power production. Well managed and operated.....	Adapted to existing buildings.
.....	None.....	Top-feeding defective. Repairs high. Dust about building. Cold air for forced draft. Plant not of modern design.....	Disposal of refuse without nuisance. Is said to save £150 ($735) per annum in fuel bills. Well operated.....	
.....	None probable..	Dust about building. Storage of refuse in open bin instead of hopper is objectionable.....	Well-constructed plant with all modern improvements. Refuse to be delivered at night by power, using street railway tracks. Day storage at central collecting stations.....	Destructor adapted to existing site and old buildings. City has franchise right to use street railway tracks from 12 P. M. to 6 A. M. daily without charge.

Complaints of nuisance due to the location of British refuse destructors in settled localities are said to be rare, and, as far as could be determined, very few of the plants visited deserved condemnation in this respect. The photographs which accompany this report indicate beyond a doubt that mixed-refuse destructors can safely be placed in central localities.

Certainly the town councilmen of Bermondsey Borough, London, would not allow a nuisance directly in the rear of the Town Hall (Figs. 1 and 2, Plate XCVII), nor would the people living about the Sheerness destructor (Figs. 3 and 4, Plate XCVII) permit an ill-smelling plant to continue in existence. At Wrexham, in Wales, (Figs. 1 and 2, Plate XCVIII), the destructor is critically situated, and at Rathmines, just outside Dublin, Ireland, the destructor is in the rear of the Town Hall (Fig. 3, Plate XCVIII), with houses near-by. In many other cases destructors are located so that any nuisance would certainly result in complaints by people living in the vicinity, and probably end by closing the plant.

It is not advisable, however, to place a refuse destructor in the midst of higher inhabited buildings, as the dust, with possibly an occasional escape of smoke, may cause some annoyance, though even this trouble can be obviated by proper attention to details in the design of the destructor building.

Types of Destructors.—In the forty plants inspected, ten different kinds of furnaces were represented, as follows:

Name of Furnace.	Number Inspected.
Meldrum	13
Horsfall	10
Heenan	6
Beaman and Deas (Meldrum)	2
Warner	3
Fryer's Improved (Manlove-Alliott and Company)	2
Fryer's	1
Sterling	1
Baker's	1
Glasgow (local design)	1

All these destructors contain large brickwork chambers having fixed grates with boilers placed outside the refuse-burning portion. In

the destruction of refuse by fire, well-determined principles of combustion apply. In order that nuisance may be prevented, it is necessary that all combustible portions of the refuse shall be completely consumed, with the result of producing the highest state of oxidation. According to Professor Thurston, the requirements for success in burning wet fuel are:

"The surrounding of the mass so completely with heated surfaces and with burning fuel that it may be rapidly dried, and then so arranging the apparatus that thorough combustion may be secured, and that the rapidity of combustion may be precisely equal to and never exceed the rapidity of desiccation. Where this rapidity of combustion is exceeded, the dry portion is consumed completely, leaving an uncovered mass of fuel which refuses to take fire."*

In practice, the destruction of refuse may be attained successfully by burning it by forced draft in a so-called Dutch oven or chamber where the brickwork is maintained at a high heat, and the escaping gases are subjected to a high temperature with an excess of air for a sufficient length of time to oxidize the combustible constituents of the material. British destructors are designed in accordance with the above principles.

The forms or types of destructors vary, however, and for convenience may be divided into two general groups.

Group 1.—The first may be termed the mutual assistance type, where one unit contains several grates with divided ash-pits, the products of combustion intermingling in the upper portion of the furnace, thus combining several furnaces or cells in one. Representatives of this type are the Meldrum and Heenan.

Group 2.—The second comprises furnaces in which each burning grate or cell forms a separate unit. The products of combustion either commingle in a general flue or combustion chamber, or pass directly from cell to boiler. Representatives of the cell type in which the products of combustion intermingle in a common chamber before passing to the boiler are the Horsfall, Sterling, and Beaman and Deas (Meldrum). Representatives of the type in which the products of combustion pass directly from the cell into contact with the boiler are the original Fryer, Fryer's Improved (Manlove-Alliott and Company), Warner, and Baker.

The Meldrum, Heenan, and Horsfall types pre-heat the air used

* "Steam Boiler Economy," Kent.

TABLE 10 (*Conti*

Reference Number.	Date visited; municipality; population; and area.	General character of population.	Collection of refuse.		Opinion on Character of Refuse.					Location of plant.	Type and description.	Erected.	Rated capacity, in tons (2 240 lb.) per 24 hours.	Appurtenance
					Estimated composition by weight.				Apparent value as a fuel.					
			Frequency.	Cost per long ton.	Ashes.	Garbage.	Rubbish.	Glass, metal, etc.	NOTE.—British refuse is dark brown to black in color—due to ash from bituminous coal.					
					%	%	%	%						
25	May 21, 1906; Rathmines (near Dublin) Urban District Council (Ireland); Pop., 35 000; Area, ...	Better type residential and stores.	Daily.....	.....	70	20	8	2	Fair. A little better in appearance than Dublin refuse.....	Central. At corporation yard in rear of Town Hall. Houses all around, nearest 100 ft. away.....	*Heenan* 2 units of 3 grates each, back hand-feed, 2 B. & W. boilers, fan draft, heated air. Chimney 150 ft.....	1905	60	Electric power station ... Supplemental coal-fire... Fan engine exhausts ... pit. Clinker crus... screening plant provi... engine badly located.
26	May 22, 1906; Belfast (Ireland); Pop., 358 680; Area, 16 475 acres.	Mixed. Business, residential, manufacturing.	.....	.....	70	20	8	2	Rather poor, great quantity of fine ash and dust.....	Isolated. On River Largan near Albert Bridge.....	*Warner*. 12 cells, back to back, top-feed, fan draft, cold air, 2 multitubular boilers, cremation chamber. Chimney 150 ft. high.....	1901	120 Burning 80	Mortar mills in operation ... serves only a portion o... Most of the refuse tip... parently destructors a... favor with authorities
										Isolated. At sewage works.....	*Meldrum*. 3 units, 8 grates in all, top-feed, 1 Lancashire boiler, steam-jet blowers, heated air. Chimney 250 ft. high. Also an old-style natural draft furnace not now in use.....	1903	75	Corrugated iron buildi... chimney. Cremating ... in destructor. Railway ... yard for sending sweep... to farmers or to city es...
27	May 23, 1906; Dalmarnock Destructor, Scotland;			In 1905 the total cost for collection and removal was 2s. 10. 3d. (71 cts.) per ton.										
28	May 23, 1906; Ruchill Destructor, Scotland;	Mixed. Business, residential, tenement, etc.	Varying with character of district...		70	20	5	5	Fair calorific value.....	Isolated. At corporation yard.....	*Fryer's Improved*. 8 cells, single row, top-feed fan draft, cold air, 2 Lancashire boilers. Chimney 200 ft.....	1902	80	Brick and corrugated ir... ing of substantial cons... Clinker crushing and s... plant. By-pass from de... to chimney. Insufficie... for the power produced
29	May 24, 1906; Kelvinhaugh Despatch Works, Scotland; Pop., 798 778; Area, 12 796 acres.									Isolated. At large corporation yard.....	Utilization depot. Household refuse and sweepings made into fertilizer, except rubbish and large particles of refuse which are burned in a natural-draft furnace.....	.....	100 tons of refuse disposed of per night.	Furnace in use is of loca... Refuse passes through ... ing screen (3-in. openi... a blade mixer where it... pounded with slop, excr... finally dropping into ... cars to be transported ... to farmers in outlying d...
30	May 28, 1906; Leeds, Municipal Corporation, England; Beckett Street Station; Pop., 456 787; Area, 21 572 acres.	Mixed. Tenements and stores contribute to Beckett Street Station.	.....	.....	80	10	5	5	Fair. Refuse in sight mainly from a poorer quarter of the district.....	Central. At corporation yard with houses nearby.....	*Horsfall*. 2 cells, back to back, top-feed by tub, water-sealed top-feeding ports, 1 B. & W. boiler, fan draft, heated air. Old Fryer destructor in adjoining building.....	1905	48	Uses chimney and boile... Fryer destructor. O... crane lifts tubs fitted w... tom doors to and ov... where the weight of t... tub opens the water-sea... ing doors; the load is ... into the cells and the doo... when weight is released.
31	May 29, 1906; Kings Norton and Northfield Urban District Council, England; Pop., 74 176; Area, ...	Better grade residential.	.....	.....	75	15	6	4	Fair. Rather wet from rains. Portion of refuse barged to destructor.....	Isolated. Near a canal on outskirts of the town	*Heenan*. 3 units of 3 grates each, back hand-feed, 3 B. & W. boilers, fan draft, heated air, superheaters. Chimney 150 ft. high.....	1905	90	Feed-water softener in op... Refuse storage hoppers ... pockets for small supply ... to be used in emergenci... for forced draft is ... through ducts running a... inside roof of the buildi... preventing the escape ... and smoke.....
32	May 29, 1906; Saltley Destructor, Birmingham, England; Pop.. ..... Area, ...	Poor people generally.	.....	.....	75	15	6	4	Fair. Some unburned lump coal visible....	Isolated at Birmingham sewage farm.....	*Heenan*. 2 units of 4 grates each, top-feed, 2 Lancashire boilers, fan draft, heated air, economizer. Chimney 165 ft. high.....	1905	85	Attractive-looking buildin... designed and constructe... supplemental coal-fired ... Electric power station ... ing.....

TABLE 10 (*Continued*).—REFUSE DESTRUCTORS VISITED IN ENGLAND, WALES, IRELAND, SCOTLAND AND CANADA. DATA, OBSERVATIONS AND DEDUCTIONS.

DATA ON PLANT.								OPERATION OF PLANT—OBSERVATIONS.				UTILIZATION OF BY-PRODUCTS.				DEDU
ype and description.	Erected.	Rated capacity, in tons (2 240 lb.) per 24 hours.	Appurtenances.	Power utilized for.	Data from builders or operators of destructors. Cost of Construction. (a) Complete. (b) Building. (c) Chimney. (d) Destructor, with boiler and accessories.	Cost of operation per long ton of refuse burned. (a) Labor. (b) Supervision. (c) Interest. (d) Sinking Fund. (e) Repairs. (f) Total.	Refuse burned per man per hour. Long tons (2 240 lb.)	Special notes on plant.	Feeding—Stoking.	Clinkering—Character of clinker.	General notes.	Approximate temperature of main flue at time of visit, in degrees, Fahrenheit.	Clinker.	Flue dust.	Tins, etc.	Reported evaporation per pound of refuse, from and at 212° fahr.	Nuisances or possible causes of complaint.	Objectionable
2 units of 3 grates back hand-feed, 2 B. & ollers, fan draft, heated Chimney 150 ft.	1905	60	Electric power station adjoining. Supplemental coal-fired boilers. Fan engine exhausts into ash-pit. Clinker crushing and screening plant provided. Fan engine badly located.	Electric lighting—public and private.	(a) £7 187 (b) $35 216 £1 517 (d) $7 433 £5 670 $27 783	(a) 6.2d (12.4c.) Only 8 months in operation.	About ½	Destructor 8 months in operation. Ample light and air about plant. Refuse furnishes power for an output of 300 kw.	Back hand-feeding from storage hopper. Stoking from clinkering side.	Ample clinkering room; good light and air; clinker hard.	Plant well managed and well operated. Working easily when visited.	1 800+	Made into mortar or concrete for footpaths. Sold.			1.78 lb. official test of 8¼ hours.	None.	Dust about pla brations of fa affects brick cells.
12 cells, back to back, d, fan draft, cold air, 2 ubular boilers, crema- hamber. Chimney 150 h.	1901	120 Burning 80	Mortar mills in operation. Furnace serves only a portion of the city. Most of the refuse tipped. Apparently destructors are not in favor with authorities.	Fan engine and mortar mills.	(a) £10 000 $49 000	(a) 9d. (18 cts.). (e) about £100 ($490) per annum.	1¼	Clinkering doors close horizontally.	Top-feeding through open ports; smoke escaping.	Ample clinkering room; clinker of fair quality.	Inexpensive plant for location. Well operated. Dusty about building.	Low; 1 200	Mortar making. Carted off.		Sold.		Smoke from feeding ports. Low temperature.	Low temperatu and smoke. used for com
3 units, 8 grates in op-feed, 1 Lancashire steam-jet blowers, air. Chimney 250 ft. Also an old-style natu- aft furnace not now in	1903	75	Corrugated iron building, brick chimney. Cremating chamber in destructor. Railway despatch yard for sending sweepings, etc., to farmers or to city estates.	Adjoining sewage works and works purposes.	(a) Complete station. £13 604 $66 660	(a) + (b) + (e) 1s.7.07 d. 39.1 cts.		Complete plant.	Top-feeding not very satisfactory; smoke escapes.	Clinkering room ample; dust from clinker about.	Clean, well-managed plant. Serves one district of Glasgow. Low cost of operation.	2 000	Mortar, concrete. Sold at 2s. 3d. (56 cts.) per ton.		Sold.		Smoke escaping from top feeding ports.	Dust about Smoke from t ing ports.
Improved. 8 cells, single top-feed fan draft. cold 2 Lancashire boilers. ney 200 ft.	1902	80	Brick and corrugated iron building of substantial construction. Clinker crushing and screening plant. By-pass from destructor to chimney. Insufficient outlet for the power produced.	Works purposes.	(a) Whole station. £20 453 $100 220	(a) + (b) + (e) 1s. 6.44d. 37.9 cts.		Complete installation carefully planned.	Top-feeding allows smoke to escape through ports.	Ample clinkering space; clinker hard.	Well-managed, clean plant, carefully operated. Low cost of destruction.	Rather low when visited. 1 400	Made into mortar or concrete, or sold.				Smoke from top feeding ports. Low temperature.	Dust about pla temperature. from top f ports. Cold combustion.
ion depot. Household and sweepings made ertilizer, except rubbish large particles of refuse are burned in a natural- furnace.		100 tons of refuse disposed of per night.	Furnace in use is of local design. Refuse passes through a revolving screen (3-in. openings) into a blade mixer where it is compounded with slop, excreta, etc., finally dropping into railway cars to be transported and sold to farmers in outlying districts.	No power available.	(a) Whole station, corporation yard, etc. £39 500 $193 550			Complete installation.	Old furnace is of top-feed type.	Furnace clinkered only once each night.	Plant carefully operated. Each day's refuse rapidly disposed of.	Old furnace not working when visited.					Smell from prepared fertilizer	Odors about pla
2 cells, back to back, ed by tub, water-sealed eding ports, 1 B. & W. fan draft, heated air. Fryer destructor in ad- g building.	1905	48	Uses chimney and boiler of old Fryer destructor. Overhead crane lifts tubs fitted with bottom doors to and over cells, where the weight of the filled tub opens the water-sealed feeding doors; the load is dumped into the cells and the doors close when weight is released.	Works purposes.	(d) £2 006 $9 829 (b) £413 $2 024		2	High-pressure fan blast, rapid consumption of refuse, large cells, substantial construction.	Tub-feeding. Each tub holds a cart-load. Water-sealed top-feeding doors. Stoking through clinkering doors.	Clinkering hot, heavy work; clinker hard.	Plant in experimental stage. Only running for a short time. Chimney area said to be inadequate.	Very high: 2 000+	Used for mortar making.			No test yet made.	None.	Dust from cli Possible high repairs. Con feeding devic
3 units of 3 grates back hand-feed, 3 B. & ollers, fan draft, heated uperheaters. Chimney high.	1905	90	Feed-water softener in operation. Refuse storage hoppers contain pockets for small supply of coal to be used in emergencies. Air for forced draft is drawn through ducts running along the inside roof of the building, thus preventing the escape of dust and smoke.	To be sold to a private electric power company.	(a) £15 000 $73 500 (b) £3 021 $9 952 (c) £846 $4 145 (d) £12 123 $59 403	(a) 7.3d. 14.6 cts. (b) 2.2d. 4.4 cts.	3/16	Plant excellent in design and construction. Can be run continuously, with 1 unit in reserve for cleaning and repairs.	Back hand-feeding from hopper. Plenty of light and air.	Clinkering from front of furnace. Ample light and air; clinker hard.	Plant well designed for ease of operation and comfort of firemen. Dust nuisance well controlled by system of ventilation.	1 800+	Used for filling adjoining land at present.			2.63 lb. in 13-hour test.	None.	Dust from clin
2 units of 4 grates top-feed, 2 Lancashire fan draft, heated air, mizer. Chimney 165 ft.	1905	85	Attractive-looking building, well designed and constructed. One supplemental coal-fired boiler. Electric power station adjoining.	Sewage pumping.	(a) £10 602 $51 950 (b) £4 214 $20 649 (c) £1 799 $8 815 (d) £4 389 $21 506	(a) 9.5d. 19 cts. (b) 1.9d. 3.8 cts.	7/16	Well-designed and operated plant. Buildings especially attractive.	Top-feeding. Stoking through clinkering doors.	Clinker removed by car on rails. Lack of light and air at clinkering level; clinker hard.	Building clean and well kept.	1 800	Used for road bottoming, bacteria beds or filling low lands.			1.82 lb. in 7-hour test.	None.	Smoke from t ports. Dust use and clin

Data from builders or operators of destructors.				Operation of Plant—Observations.				Utiliz
Cost of Construction. (a) Complete. (b) Building. (c) Chimney. (d) Destructor, with boiler and accessories.	Cost of operation per long ton of refuse burned. (a) Labor. (b) Supervision. (c) Interest. (d) Sinking Fund. (e) Repairs. (f) Total.	Refuse burned per man per hour. Long tons (2 240 lb.)	Special notes on plant.	Feeding—Stoking.	Clinkering—Character of clinker.	General notes.	Approximate temperature of main flue at time of visit, in degrees, Fahrenheit.	Clinker.
(a) £7 187 $35 216 (b) £1 517 $7 433 (d) £5 670 $27 783	(a) 6.2d (12.4c.) Only 8 months in operation.....	About ½	Destructor 8 months in operation. Ample light and air about plant. Refuse furnishes power for an output of 300 kw.....	Back hand-feeding from storage hopper. Stoking from clinkering side ...	Ample clinkering room; good light and air; clinker hard.....	Plant well managed and well operated. Working easily when visited.....	1 800+	Made into mortar concrete for foo paths. Sold....
(a) £10 000 $49 000	(a) 9d. (18 cts.). (e) about £100 ($490) per annum ..	1¼	Clinkering doors close horizontally	Top-feeding through open ports; smoke escaping.....	Ample clinkering room; clinker of fair quality.....	Inexpensive plant for location. Well operated. Dusty about building.....	Low; 1 200	Mortar making Carted off.....
(a) Complete station. £13 604 $66 660	(a) + (b) + (e) 1s.7.07 d. 39.1 cts ..	.....	Complete plant	Top-feeding not very satisfactory; smoke escapes....	Clinkering room ample; dust from clinker about.....	Clean, well-managed plant. Serves one district of Glasgow. Low cost of operation.....	2 000	Mortar, concret Sold at 2s. 3d. (cts.) per ton....
(a) Whole station. £20 453 $100 220	(a) + (b) + (e) 1s. 6.44d. 37.9 cts...	.....	Complete installation carefully planned....	Top-feeding allows smoke to escape through ports....	Ample clinkering space; clinker hard.....	Well-managed, clean plant, carefully operated. Low cost of destruction.....	Rather low when visited. 1 400	Made into mortar concrete, or sold
(a) Whole station, corporation yard, etc. £39 500 $193 550	.....	.....	Complete installation..	Old furnace is of top-feed type.....	Furnace clinkered only once each night.....	Plant carefully operated. Each day's refuse rapidly disposed of.....	Old furnace not working when visited.	.....
(d) £2 006 $9 829 (b) £413 $2 024	.....	2	High-pressure fan blast, rapid consumption of refuse, large cells, substantial construction.....	Tub-feeding. Each tub holds a cart-load. Water-sealed top-feeding doors. Stoking through clinkering doors..	Clinkering hot, heavy work; clinker hard.....	Plant in experimental stage. Only running for a short time. Chimney area said to be inadequate.....	Very high: 2 000+	Used for mort making .....
(a) £15 000 $73 500 (b) £2 031 $9 952 (c) £846 $4 145 (d) £12 123 $59 408	(a) 7.3d. 14.6 cts. (b) 2.2d. 4.4 cts.	7/16	Plant excellent in design and construction. Can be run continuously, with 1 unit in reserve for cleaning and repairs	Back hand-feeding from hopper. Plenty of light and air.....	Clinkering from front of furnace. Ample light and air; clinker hard..	Plant well designed for ease of operation and comfort of firemen. Dust nuisance well controlled by system of ventilation.....	1 800+	Used for filling joining land present.....
(a) £10 602 $51 950 (b) £4 214 $20 649 (c) £1 799 $8 815 (d) £4 389 $21 506	(a) 9.5d. 19 cts. (b) 1.9d. 3.8 cts.	7/16	Well-designed and operated plant. Buildings especially attractive.....	Top-feeding. Stoking through clinkering doors.....	Clinker removed by car on rails. Lack of light and air at clinkering level; clinker hard.....	Building clean and well kept.	1 800	Used for road b toming, bacte beds or filling l lands.....

Utilization of By-Products.				Deductions.			
r.	Flue dust.	Tins, etc.	Reported evaporation per pound of refuse, from and at 212° fahr.	Nuisances or possible causes of complaint.	Objectionable features.	Commendable features.	Remarks.
ortar or or foot- d.....	.....	.....	1.78 lb. official test of 8½ hours.....	None.....	Dust about plant. Vibrations of fan engine affects brickwork of cells.....	Well-constructed and well-managed plant. Good power production. Back hand-feeding and front-clinkering advantageous.....	
king.	.....	Sold.....	.....	Smoke from feeding ports. Low temperature.....	Low temperature, dust and smoke. Cold air used for combustion..	Inexpensive plant doing a fair amount of work..	
oncrete. . 3d. (56 on.....	.....	Sold.....	.....	Smoke escaping from top feeding ports.....	Dust about plant. Smoke from top feeding ports.....	High temperature. Low cost of operation. Excellent management and operation.....	
ortar or or sold..	.....	.....	.....	Smoke from top feeding ports. Low temperature.....	Dust about plant. Low temperature. Smoke from top feeding ports. Cold air for combustion.....	Well-built, carefully operated plant. Low cost of operation.....	The whole scheme of refuse disposal in Glasgow shows careful planning over a period of years, resulting in economy and efficiency. Night collection of refuse is the rule.
.....	.....	.....	.....	Smell from prepared fertilizer	Odors about plant.....	Economical means of disposal, but not very sanitary. Plant carefully operated.....	
mortar	.....	.....	No test yet made.....	None.....	Dust from clinkering. Possible high cost of repairs. Complicated feeding devices.....	High rate of burning. No handling of refuse. Cool storage of refuse. Probable economy in labor cost of destroying the refuse.....	The old Fryer destructor consists of 14 cells; top feed, with Horsfall steam jet blowers. The two new Horsfall cells will destroy as much refuse per day as seven of the old Fryer cells.
lling ad- land at	.....	.....	2.63 lb. in 18-hour test.....	None.....	Dust from clinker yard.	Excellent plant in design and construction. Independent destructor units. Controlled ventilation. No supplemental coal-fired boiler plant.....	
oad bot- bacteria lling low	.....	.....	1.82 lb. in 7-hour test.....	None.....	Smoke from top feeding ports. Dust from refuse and clinker.....	Attractive building. Well-designed, constructed and operated plant. Said to save £1 000 ($4 900) per annum in coal bills.....	Top feeding required by authorities.

for combustion to a temperature from 200 to 400° fahr. before it comes in contact with the burning fuel on the grate. Other makes of furnaces mentioned in Group 2 use air at ordinary atmospheric temperature. The utilization of heated air undoubtedly tends to more perfect combustion and higher temperatures both in cell and combustion chamber. Other differences in design, in the furnaces in Groups 1 and 2, may be noted, as for instance, the drying hearth which some furnace makers consider essential in the destruction of refuse, the use of steam-jet blowers or fans for forced draft, the different provisions for arresting dust, the kind of boilers used, the various methods of feeding, clinkering, stoking, etc. All the above-named destructors, except the original Fryer, use forced draft, which is considered necessary for the attainment of a high temperature.

The aim in the design of refuse destructors should be to maintain a steady temperature. If it be considered that 1 250° fahr. is the minimum at which septic poisons in the products of combustion are destroyed, the higher limit of temperature is fixed by the materials used in the construction of the furnace. Temperatures greater than 2 000° fahr. are apt to result in high cost of repairs. Thus temperatures between 1 250 and 2 000° fahr. are desirable, both from sanitary and economical points of view. As the burning of refuse in a destructor is an intermittent process, requiring alternate charging and clinkering, the fluctuations in temperature should be minimized as much as possible. When destructors are of such design that the gases pass directly from cell to boiler without an intermediate combustion chamber, there is danger of unoxidized gases being cooled, by contact with the boiler, below the temperature required to prevent nuisance.

In general, modern British types of destructor vary in important details, and, of the different plants examined by the writer, those in which a combustion chamber or flue was placed between the cell (or unit) and the boiler, and where heated air was used for combustion, appeared to be doing the most satisfactory work.

Power from Refuse.—Of the forty plants inspected, all but two produced steam for power purposes, as follows:

Power Used For:	Number of Plants.
Electric lighting and power stations	16
Sewage pumping	7
Works purposes	14
Water pumping	1

In considering the utilization of power from refuse, it should be borne in mind that power is a secondary consideration, and that the primary object is to destroy refuse in a sanitary and economical manner.

At electric lighting and power stations, the demand for lighting purposes generally occurs for a short period in the evening, when an output very much higher than the ordinary working load is required. With refuse which is of low calorific value, and requires burning at a high rate to produce power, this means that the fires must be rushed, and consequently there is likelihood of incomplete combustion. Supplementary coal-fired boilers are usually found in connection with destructor-electric-lighting stations, or else the destructor is of much greater capacity than would be required to deal with the refuse only. The combination of refuse destructor and electric lighting plant may be economical, yet, if other means are available, whereby the power resulting from the destruction of refuse can be utilized regularly as produced and the furnace operated continuously at an easy working rate, this method should prove more desirable than electric lighting utilization. At the sewage pumping stations visited, the quantity to be pumped was usually insufficient to keep the destructor continuously in operation. Pumping water by the power produced from refuse would seem to be the most satisfactory method of utilization, but the conditions where such a system can be used are exceptional.

If no other outlet for the energy produced in burning the waste material is available, the power is used for what has been termed "Works Purposes," that is, crushing clinker, screening it into different sizes, mixing it with mortar, cement, or lime, to form bricks, slabs, etc., also for lighting the destructor depots or adjoining corporation yards, and the steam heating of neighboring public baths or libraries.

It is undoubtedly advisable to provide means for utilizing heat resulting from the destruction of city wastes, for the purpose of decreasing the cost of final disposition. At the same time, it should be kept in mind that a sanitary disposal of refuse is the primary consideration. There were indications at some refuse destructor plants in Great Britain of a tendency to slight the main factor of sanitary disposal.

Capital Cost of Destructor Installations.—The cost of construction of destructor installations varies greatly according to local conditions,

Reference Number.	Date visited; municipality; population; and area.	General character of population.	Collection of refuse.		Opinion on Character of Refuse.					Location of plant.	Type and description.	Erected.	Rated capacity, in tons (2 240 lb.) per 24 hours.	Appurtenance
					Estimated composition by weight.				Apparent value as a fuel.					
			Frequency.	Cost per long ton.	Ashes.	Garbage.	Rubbish.	Glass, metal, etc.	Note.—British refuse is dark brown to black in color—due to ash from bituminous coal.					
					%	%	%	%						
33	May 29, 1906; Birmingham Municipal Corporation, England; Montague Street Depot; Pop., 522 204; Area, 12 639 acres.	Mixed. Mainly poor people contribute to the Montague Street depot.	.....	.....	60	25	10	5	Fair. Large proportion of green vegetable matter in sight.	Central. Surrounded by tenements. General corporation station	*Heenan.* 1 unit of 4 grates, top-feed, 1 Lancashire boiler, fan draft, heated air, old chimney in use; old type of destructors adjoining.....	1904	40	Heenan destructor re furnace. 3 other d structors in operati utilization in progre poration yard oddl All sorts of muni under way at this d
34	May 30, 1906; Bradford Municipal Corporation, England; Hammerton Street Destructor;	Mixed. Business, etc.	Ash-pits cleaned 11.1 times per annum. Night collections the rule.....	38.15 pence or 76.3 cents.	65	10 night soil 20 30	3	2	Poor. Large amount of wet night-soil in refuse.....	Central. In general corporation yard.....	*Horsfall.* 12 cells, 2 rows, back to back, top-feed, 2 multitubular boilers, steam-jet blowers, heated air, cremating chamber. Chimney 180 ft. high.....	1897	120 Burning 59 tons per day.	Corrugated iron buil plete clinker, utili consisting of crushe mortar mills, etc. quired for a very c nicipal repair pla by destructor.....
35	May 30, 1906; Sunbridge Road Destructor; Pop. 285 589; Area, 22 843 acres.									Central. Houses on one side about 100 ft. away.....	*Horsfall.* 12 cells, single row top-feed 2 B. & W. boilers (marine type), steam-jet blowers, heated air, economizer, chimney 180 ft. high; cremating chamber	1903	120 Nominal	Brick building and old plant reconstru head clinker railw mill plant .....
36	May 30, 1906; Manchester, England; Moss Side Destructor; Pop., 631 185; Area, 19 893 acres.	Mainly residential.	.....	.....	60	20	10	10	Fair. Dry.....	Central. Houses on three sides, 1 row about 50 ft. away.....	*Horsfall.* 6 cells, back hand-feed. 2 B. & W. boilers, steam-jet blowers, heated air. Chimney 90 ft. high, dust catcher.....	1901	60	Attractive-looking ings, separate clin and screening bui head clinker railwa
37	May 31, 1906; Batley Municipal Corporation, England; Pop., 30 321; Area, 2 039 acres.	Residential, business, manufacturing.	As required..	.....	.....	.....	.....	.....	Fair. Mainly ashes with some night-soil, very little garbage or rubbish. Moist..	Isolated. In valley with houses on hills above top of chimney.....	*Horsfall.* 3 cells, back hand-feed, 1 Lancashire boiler, steam-jet blowers, heated air, economizer and dust catcher. Chimney 180 ft. high	1904	30	Substantial buildi lighting station coal-fired boiler pl
38	May 31, 1906; Ilkley Urban District Council, England; Resident Pop., 8 000; Summer Pop., 25 000; Area, ...	Health resort—residential, hotel and boarding house.	.....	.....	30	30	30	10	Poor. Mainly green garden refuse and rubbish	Isolated. At sewage farm.....	*Horsfall.* 2 cells, back hand-feed, 1 multitubular boiler, steam-jet blowers, heated air, dust catcher. Chimney 60 ft. high	1905	20	Substantial brick chimney. Chamb ing dead animals,
39	June 15, 1906; Worthing Municipal Corporation, England; Resident Pop., 26 000; Summer Pop., 36 000; Area, 3 012 acres.	Seaside resort. Good type residences, better class of residents.	.....	.....	30	40	20	10	Poor. Mainly green garden refuse and rubbish.....	Isolated. At sewage farm.....	*Heenan.* 1 unit of 2 grates, back hand-feed, 1 B. & W. boiler, fan draft, heated air. Cremating chamber.....	1905	25 Burning 18	Attractive-looking buildings. Pump sists of 2 gas steam engines r structor. Gas e emergencies and is available.....
40	Aug. 7, 1906; Westmount (Dominion of Canada); Pop., 11 000; Area, 1 000 acres.	Suburban; residential.	Daily	.....	40	40	15	5	Fair. Dry refuse with anthracite ash. Large amount of rubbish.....	Isolated. Nearest house 600 to 800 ft. away....	*Meldrum.* 1 unit of 3 grades, top-feed, steam-jet blowers, heated air, 1 B. & W. boiler, with superheater. Chimney 150 ft. high....	1906	50	Substantial brick stories high, fla drive on roof an steel storage hop boilers, coal-fired Destructor has by-pass for gas with cold air inl cool the gases the chimney, wh lined throughou with iron bands

TABLE 10 (*Continued*).—REFUSE DESTRUCTORS VISITED IN ENGLAND, WALES, IRELAND, SCOTLAND AND CA

DATA ON PLANT.									
Type and description.	Erected.	Rated capacity, in tons (2 240 lb.) per 24 hours.	Appurtenances,	Power utilized for:	Data from builders or operators of destructors.			Special notes on plant.	Feeding—Stok
					Cost of construction: (a) Complete. (b) Building. (c) Chimney. (d) Destructor, with boiler and accessories.	Cost of operation per long ton of refuse burned. (a) Labor. (b) Supervision. (c) Interest. (d) Sinking Fund. (e) Repairs. (f) Total.	Refuse burned per man, per hour. Long tons (2 240 lb.)		
n. 1 unit of 4 grates, top-, 1 Lancashire boiler, fan t, heated air, old chim- in use; old type of de- tors adjoining.....	1904	40	Heenan destructor replaced old furnace. 3 other old-style destructors in operation. Clinker utilization in progress. Old corporation yard oddly arranged. All sorts of municipal work under way at this depot.....	Works purposes..... ..	(d) £3 000 $14 700	(a) 10d 20 cts. (e) £6 ($29.40) in 18 mos. of operation.	⅔	Old reduction plant removed to make room for Heenan destructor.....	Top feeding. and dusty Storage bin refuse.....
ll. 12 cells, 2 rows, back ack, top-feed, 2 multi- lar boilers, steam-jet ers, heated air, cremat- chamber. Chimney 180 igh.....	1897	120 Burning 59 tons per day.	Corrugated iron building. Complete clinker, utilization plant consisting of crusher, flag press, mortar mills, etc. All power required for a very complete municipal repair plant furnished by destructor.....	Work purposes.....	.....	(a) Year 1905 11.75d. or 23½ cts.	1	With 6 cells working 190 i. h. p. is produced from the refuse.....	Top feeding, a slight smoke cape from ar feeding ports.
ll. 12 cells, single row eed 2 B. & W. boilers ine type), steam-jet ers, heated air, econo- r, chimney 180 ft. high; ating chamber	1903	120 Nominal	Brick building and chimney—an old plant reconstructed. Overhead clinker railway. Mortar mill plant	Electric street railway, mortar mills.....	.....	(a) Year 1905 11.57d. or 23.14 cts.	1	Large destructor dealing with poor class of refuse. Generating 61 electric units per ton of refuse burned.....	Top feeding a some smoke cape from po
ll. 6 cells, back hand- 2 B. & W. boilers, n-jet blowers, heated air. ney 90 ft. high, dust er.....	1901	60	Attractive-looking brick buildings, separate clinker crushing and screening building. Overhead clinker railway.....	Works purposes. Mortar making, lighting plant, steam to public baths	(d) £3 645 $17 860	(a) 6.75d. 13.5 cts. (e) About £25 ($122.50) per annum.	1	Well-designed and constructed plant. Only a part of the power utilized.....	Back hand-feed poor type of ing doors. S issuing from ing doors.....
ll. 3 cells, back hand- 1 Lancashire boiler, n-jet blowers, heated economizer and dust er. Chimney 180 ft.	1904	30	Substantial building. Electric-lighting station nearby with coal-fired boiler plant.....	Electric lighting.....	(d) £3 705 $18 155	(a) 13.54d. 27 cts. (e) About £19 ($93) for 1905.	⅔	Horizontal back-feeding doors allow smoke to escape. Storage bin open, refuse collects around feeding doors.....	Back hand-fee Stoking from ering doors..
ll. 2 cells, back hand- 1 multitubular boiler, n-jet blowers, heated air, catcher. Chimney 60 ft.	1905	20	Substantial brick building and chimney. Chamber for cremating dead animals, etc.....	Mortar mill.....	(a) £1 433 $7 022 (d) £1 080 $5 047	.....	1	Refuse stored in open bin collects around feeding doors. Only portion of power used.	Back hand-fee Dusty.....
n. 1 unit of 2 grates, hand-feed, 1 B. & W. r, fan draft, heated air. ating chamber.....	1905	25 Burning 18	Attractive-looking plant—brick buildings. Pumping plant consists of 2 gas engines and 2 steam engines run from destructor. Gas engine used in emergencies and when no refuse is available.....	Sewage pumping.....	(b) £1 100 $5 390 (c) £478 $2 342 (d) £2 800 $13 720	(a) 6.3d. 12.6 cts. (e) No repairs in 18 mos.	About ½ when visited.	Destructor and gas engines make a good combination. Well-constructed plant—clean	Back-feeding. ple room, ligh air.....
m. 1 unit of 3 grades, eed, steam-jet blowers, d air, 1 B. & W. boiler, superheater. Chimney t. high.....	1906	50	Substantial brick building, 2 stories high, flat roof, carts drive on roof and dump into a steel storage hopper, 2 B. & W. boilers, coal-fired, are provided. Destructor has drying hearth, by-pass for gases to chimney with cold air inlet to dilute and cool the gases before reaching the chimney, which is fire-brick lined throughout and reinforced with iron bands.....	Electric lighting.....	(c) About $6 000 (d) About $18 500	In operation since April, 1906.	.....	Steel refuse hopper. Substantial buildings. Electric lighting generators in separate building adjoining...	Rear stokin same lev clinkering do

CANADA. DATA, OBSERVATIONS AND DEDUCTIONS.

Operation of Plant—Observations.				Utilization of By-Products.				Deductio	
—Stoking.	Clinkering—Character of clinker.	General notes.	Approximate temperature of main flue at time of visit, in degrees, Fahrenheit.	Clinker.	Flue dust.	Tins, etc.	Reported evaporation per pound of refuse, from and at 212° fahr.	Nuisances or possible causes of complaint.	Objectionable featu
ng. Dark sty room. bin for	Ample light and air in clinkering space. Clinker hard.....	Plant well operated	1 800	Used for mortar and slab making.....	.....	Solder extracted, baled and sold.	1.56 lb. in 9½-hour test...	None.....	Dust. Smoke from feeding ports.....
ng, allows noke to es- om around ports.....	Ample clinkering room. Clinker hard.....	Plant well managed and well operated. Fertilizer made from fish remains commands a ready market	1 800	Used for mortar or clinker concrete slabs.....	.....	Sold at 10s. ($2 50) per ton.	88/100 lb. in 11½-day test.....	None	Night-soil mixed w refuse causes an o inside the buildi Smoke from top-fe ing ports. Dust fr clinkering .....
ing allows noke to es- om ports...	Ample clinkering room. Clinker fair in quality.....	Well-managed and well-operated plant. Only a portion of the clinker utilized.....	1 800	Used for making mortar.....	.....	.....	1.25 lb. in 7-day test ..	None.....	Odor from refuse storage. Smoke fr top-feeding po Dust from clinkeri
d-feeding— pe of feed- rs. Smoke from feed- rs.....	Front clinkering. Clinker rather poor in quality—some unburned particles in clinker heaps...	Very dusty inside building. Open storage of refuse in bin a disadvantage.	1 800	Used for mortar making or carted off..	.....	.....	1 25 lb. in 4.8-hour test	None.....	Smoke from feedi doors. Poor syst of refuse stora Dust in and ab building. Unburn particles in clinker
nd-feeding. from clink- oors.....	Clinkering room ample, well lighted and ventilated. Clinker not hard..	Well-managed and well-operated plant, producing a large amount of power.....	1 800+	Not utilized at present. Carted off,..	.....	.....	1 258 lb average for 1 year's run of plant.....	None.....	Refuse bin open. Smo from back-feedi doors. Dust fr clinker..... .....
nd-feeding.	Clinkering room ample—plenty of light and air. Clinker fair in quality.....	Well operated.....	1 800	Used for filtering medium at sewage works. Made into mortar.....	.....	.....	.....	None.....	Poor system of refu storage. Dust ab building .....
ding. Am- m, light and	Clinkering room ample. Clinker only 15% of refuse.....	Well-managed and well-operated plant. Saves in gas bills about £170 ($833) per annum.....	1 500 to 1 800	Used for sidewalks. Experiments with clinker and coal tar roadways in progress.....	.....	Sold	1.69 lb. in 6½-hour test.....	None	Dust from clinkeri Slight smoke fr feeding doors impr erly operated.....
stoking on level as ring doors...	Clinkering from front. Clinker dropped through doors in floor to ground level below. Clinker hard.	Destructor working easily when visited. Not enough refuse available to keep it working more than 10 hours	About 1 500	Used for road bottoming, sidewalk base and for filling.	.....	.....	1.36 lb. in 8½-hour test on May 2, 1906.....	None.....	Smoke escapes fr top-feeding do when stoking. So dust about buildi but not much.....

TRUCTORS VISITED IN ENGLAND, WALES, IRELAND, SCOTLAND AND CANADA. DATA, OBSERVATIONS AND DEDUCTIONS.

	Data from builders or operators of destructors.				Operation of Plant—Observations.				Utiliz
	Cost of construction: (a) Complete. (b) Building. (c) Chimney. (d) Destructor, with boiler and accessories.	Cost of operation per long ton of refuse burned. (a) Labor. (b) Supervision. (c) Interest. (d) Sinking Fund. (e) Repairs. (f) Total.	Refuse burned per man, per hour. Long tons (2 240 lb.)	Special notes on plant.	Feeding—Stoking.	Clinkering—Character of clinker.	General notes.	Approximate temperature of main flue at time of visit, in degrees, Fahrenheit.	Clinker.
	(d) £3 000 $14 700	(a) 10d 20 cts. (e) £6 ($29.40) in 18 mos. of operation.	⅔	Old reduction plant removed to make room for Heenan destructor.	Top feeding. Dark and dusty room. Storage bin for refuse.	Ample light and air in clinkering space. Clinker hard.	Plant well operated	1 800	Used for mortar a slab making.
		(a) Year 1905 11.75d. or 23½ cts.	1	With 6 cells working 190 i. h. p. is produced from the refuse.	Top feeding, allows slight smoke to escape from around feeding ports.	Ample clinkering room. Clinker hard.	Plant well managed and well operated. Fertilizer made from fish remains commands a ready market	1 800	Used for mortar clinker concre slabs.
		(a) Year 1905 11.57d. or 23.14 cts.	1	Large destructor dealing with poor class of refuse. Generating 61 electric units per ton of refuse burned.	Top feeding allows some smoke to escape from ports.	Ample clinkering room. Clinker fair in quality.	Well-managed and well-operated plant. Only a portion of the clinker utilized.	1 800	Used for makin mortar.
	(d) £3 645 $17 860	(a) 6.75d. 13.5 cts. (e) About £25 ($122.50) per annum.	1	Well-designed and constructed plant. Only a part of the power utilized.	Back hand-feeding—poor type of feeding doors. Smoke issuing from feeding doors.	Front clinkering. Clinker rather poor in quality—some unburned particles in clinker heaps.	Very dusty inside building. Open storage of refuse in bin a disadvantage.	1 800	Used for morta making or carte off.
	(d) £3 705 $18 155	(a) 13.54d. 27 cts. (e) About £19 ($93) for 1905.	⅔	Horizontal back-feeding doors allow smoke to escape. Storage bin open, refuse collects around feeding doors.	Back hand-feeding. Stoking from clinkering doors.	Clinkering room ample, well lighted and ventilated. Clinker not hard.	Well-managed and well-operated plant, producing a large amount of power.	1 800+	Not utilized at pre ent. Carted off,
	(a) £1 433 $7 022 (d) £1 080 $5 047		1	Refuse stored in open bin collects around feeding doors. Only portion of power used.	Back hand-feeding. Dusty.	Clinkering room ample—plenty of light and air. Clinker fair in quality.	Well operated	1 800	Used for filterin medium at sewag works. Made int mortar.
	(b) £1 100 $5 390 (c) £478 $2 342 (d) £2 800 $13 720	(a) 6.3d. 12.6 cts. (e) No repairs in 18 mos.	About ½ when visited.	Destructor and gas engines make a good combination. Well-constructed plant—clean	Back-feeding. Ample room, light and air.	Clinkering room ample. Clinker only 15% of refuse.	Well-managed and well-operated plant. Saves in gas bills about £170 ($833) per annum.	1 500 to 1 800	Used for sidewalk Experiments wit clinker and co tar roadways progress.
	(c) About $6 000 (d) About $18 500	In operation since April, 1906.		Steel refuse hopper. Substantial buildings. Electric lighting generators in separate building adjoining.	Rear stoking on same level as clinkering doors.	Clinkering from front. Clinker dropped through doors in floor to ground level below. Clinker hard.	Destructor working easily when visited. Not enough refuse available to keep it working more than 10 hours	About 1 500	Used for road bo toming, sidewa base and for fillin

Utilization of By-Products.			Reported evaporation per pound of refuse, from and at 212° fahr.	Deductions.			Remarks.
	Flue dust.	Tins, etc.		Nuisances or possible causes of complaint.	Objectionable features.	Commendable features.	
tar and g.....	.....	Solder extracted, baled and sold.	1.56 lb. in 9½-hour test...	None.....	Dust. Smoke from top feeding ports.....	Modern style destructor, producing a fair amount of power. Well operated.....	Plant adapted to existing layout. Top-feeding required by authorities.
rtar or oncrete	.....	Sold at 10s. ($2 50) per ton.	88/100 lb. in 11½-day test.....	None	Night-soil mixed with refuse causes an odor inside the building. Smoke from top-feeding ports. Dust from clinkering	Destruction of poor quality refuse at high temperatures, without nuisance. Economy of operation. Utilization of clinker.....	The total cost of refuse destruction for the year 1905 was 43.05 pence (86.1 cents) per ton. The whole scheme of refuse destruction shows careful planning over a period of years, and results in economy and efficiency of operation.
making	.....	.....	1.25 lb. in 7-day test ..	None.....	Odor from refuse on storage. Smoke from top-feeding ports. Dust from clinkering.	Economy of operation. Destruction of a poor quality of refuse at high temperature and without nuisance. Fair power production.....	
mortar carted	.....	.....	1 25 lb. in 4,8-hour test	None.....	Smoke from feeding doors. Poor system of refuse storage. Dust in and about building. Unburned particles in clinker...	Substantial and attractive buildings. High temperature.....	
at pressed off,..	.....	.....	1 258 lb average for 1 year's run of plant.....	None.....	Refuse bin open. Smoke from back-feeding doors. Dust from clinker	Excellent management. Economy of operation. Excellent power production. Substantial plant.....	
filtering t sewage lade into	.....	.....	.....	None.....	Poor system of refuse storage. Dust about building	Good plant for a small town. High temperature.....	
dewalks. nts with nd coal ways in	.....	Sold	1.69 lb. in 6½-hour test.....	None	Dust from clinkering. Slight smoke from feeding doors improperly operated.....	Well-designed, constructed and operated installation. Gas engine combination excellent. Use of clinker with tar on roadways with light travel promising.....	
road bot- sidewalk or filling.	.....	.....	1.36 lb. in 8½-hour test on May 2, 1906.....	None.....	Smoke escapes from top-feeding doors when stoking. Some dust about building, but not much.....	Plant well designed and constructed. Gave excellent results in power production on test. System of clinkering and dropping hot clinker to floor below.....	When destructor was visited a test of the electrical installation was under way.....

and figures for British plants would hardly apply in the United States. It appears from the data obtained, however (the details of which are given in Table 10), that the average cost of eighteen destructors would amount to about $4 470 per cell or grate, including the furnace with boiler and appurtenances, but excluding chimney, building and runway.

Cost of Operation.—The cost of operation, for different plants quoted in Table 10, was obtained from the engineer or superintendent in charge of the destructor or from the furnace makers. Some of the figures given are from official reports covering a year's work, while others are for short periods only. From the data, it appears that for twenty-four installations the average cost of labor per long ton (2 240 lb.) of refuse destroyed would amount to 24.3 cents, or 21.5 cents per short ton (2 000 lb.). As the American rate of laborers' wages is about double the British rate, this would make 43 cents per short ton of refuse destroyed on an American basis.

For supervision, only four installations had figures available, the average being 4.83 cents per long ton. Two plants reported the cost for repairs at 3.22 cents per long ton.

Only one complete report was obtained in which all charges for the destruction of refuse, including labor, supervision, interest on capital, sinking fund, repairs and supplies, were included. The total cost of operation, including all the above charges at Stoke-upon-Trent, amounted to $1.17 per long ton or $1.04 per short ton. By changing the labor rate so that it would compare with American conditions, and by assuming the same charges for interest, sinking fund and repairs, it would appear that the total cost of refuse destruction for a plant similar to that at Stoke-upon-Trent would amount to $1.50 per short ton in New York.

Of the various figures tabulated for the labor cost per long ton of refuse destroyed, it will be found that eleven destructors—in which refuse is fed into the furnace by hand—returned an average cost of 21.6 cents as against 27.3 cents for eleven top-fed destructors. Some figures used in making up the foregoing results for hand-fed plants covered only a short period of time. It is of interest, however, to note that hand-feeding does not seem to be more costly than top-feeding.

Refuse Burned per Man per Hour.—Definite information regarding the quantity of refuse handled per man per hour (assuming the

quality of labor to be comparable) affords a better general means for arriving at the labor cost of operating a destructor. From the figures for twenty-seven plants, on an average, each man employed would handle 0.78 long tons or 0.88 short tons per hour, varying from 0.5 to 2 long tons per hour with the type of plant and method of operation. At an easy rate of working, there should be no difficulty in destroying 0.75 short tons per man per hour; hence, with wages at 25 cents per hour (or $2 per day), the cost of labor would amount to 33⅓ cents per ton, while at 31¼ cents per hour (or $2.50 per day), the cost would be about 42 cents per ton.

Special Notes on Destructors.—In glancing over the various photographs which accompany this paper, it will be apparent that the English destructor is most substantially constructed, and that the buildings are intended for long service. From an examination of the various older furnaces, it would appear that the destructor portion, with ordinary care in operation, should last at least fifteen years.

As the appearance of a refuse installation has an important bearing on public opinion regarding the plant, it is of particular importance that the building should be made attractive, architecturally. The interior should have ample light, air, and provision for the comfort of the men employed, including baths and toilet facilities. These features have received consideration in Great Britain, as some of the photographs indicate.

Another factor requiring consideration is the extent of ground surrounding the destructor building. Ample land should be provided, if possible, so that dust may not cause complaint from neighboring householders.

Operation of Plant—Observations.—In the time spent at the various installations, many features of interest undoubtedly escaped attention, and perhaps some of the comments in Table 10 would hardly be warranted if some days instead of hours had been given to each. The recorded observations, however, indicate the conditions at the time the plant was visited. Generally speaking, from the appearance of the destructors, no special preparations were made because of the writer's visit, and in many cases no warning was given to those in charge.

Feeding—Charging.—Of the forty destructors, sixteen were of the top-fed variety, in which refuse was charged through ports on top of

FIG. 2.—WALTHAMSTOW DESTRUCTOR AT SEWAGE FARM, WITH PRECIPITATION TANKS IN FOREGROUND.

FIG. 4.—COMBINED DESTRUCTOR AND SEWAGE PUMPING STATION AT WORTHING.

PLATE CV.
PAPERS, AM. SOC. C. E.
NOVEMBER, 1907.
FETHERSTON ON
REFUSE DESTRUCTION.

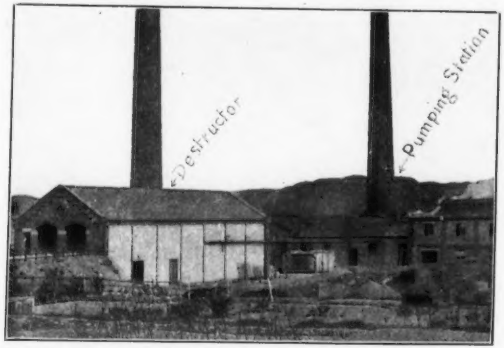


FIG. 1.—WATFORD DESTRUCTOR, SEWAGE PUMPING STATION, AND ELECTRIC LIGHTING PLANT.

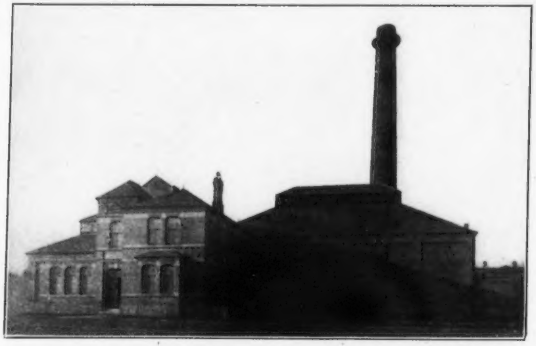


FIG. 3.—COMBINED ELECTRIC LIGHTING AND DESTRUCTOR STATION AT STOKE-UPON-TRENT.

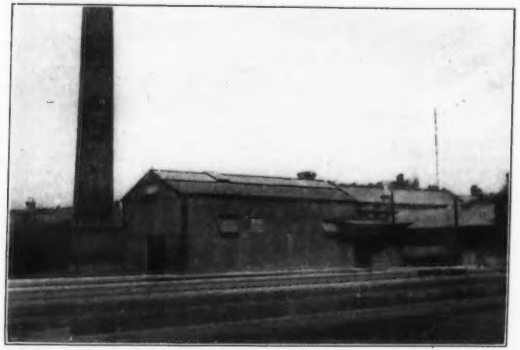


FIG. 2.—WALTHAMSTOW DESTRUCTOR AT SEWAGE FARM, WITH PRECIPITATION TANKS IN FOREGROUND.

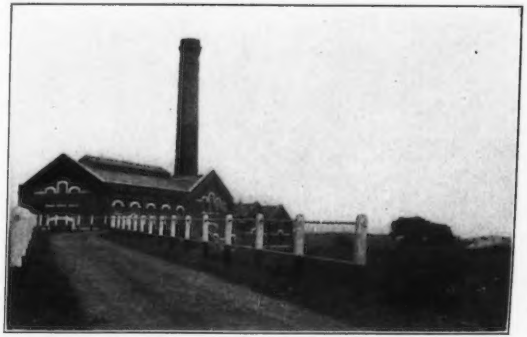


FIG. 4.—COMBINED DESTRUCTOR AND SEWAGE PUMPING STATION AT WORTHING.

the furnaces, and these sixteen represented nine different types. Three installations were top-fed by cart direct, and represented two types of furnace. By "cart fed direct" is meant that cart storage of refuse was necessary, and when the furnace was ready for charging each cartload was dumped directly into the cell. One furnace was top-fed by a so-called "tub-feeding" method. In this case, each cart was tipped at the ground level into a box or tub with hinged bottom doors. The tub was then elevated by a traveling crane, and the charge of refuse was dropped into the cell through water-sealed mechanically-operated doors on the top of the furnace. One destructor was top-fed by a patent charging truck. Here, also, refuse was elevated by power, dropped into a truck on wheels, and charged into the furnace as required. Eleven destructors were hand-fed at the front by shovel, and represented two types. Eight destructors were hand-fed by shovel at the back, and represented three types.

In commenting upon the different methods of charging destructors, it appears that the top-feeding method (except where water-sealed doors are used) allows smoke to escape. Even with water-sealed doors, smoke escapes when charging. Of the hand-firing methods, the front-fed type appears to be advantageous, with regard to concentration of labor and freedom from escaping smoke, but the storage bin cuts off light and air from the firemen, while some refuse may be mixed with clinker if the men are careless. With back hand-feeding by shovel, ample light and air can be given on the clinkering side of the furnace where it is most needed. As compared with front-feeding, back hand-feeding does not permit of the same concentration of labor, but allows greater comfort to the men employed, which more than compensates for this slight disadvantage.

In general, shovel-feeding obviates escaping smoke from top-feeding doors, allows a better selection of refuse, and does away with stoking to a great extent, as refuse can be charged directly on the grate, thus saving one operation in destroying the material. When the refuse has not reached an advanced stage of decomposition, and does not contain an excess of water, or such objectionable material as night-soil, hand-firing is undoubtedly to be preferred, especially for power plants.

Stoking.—By stoking is meant the dragging, pushing or spreading of refuse after it has been charged into the furnace. All top-fed

destructors and all destructors provided with drying hearths require considerable stoking. Hand-fed types, without drying hearths, where refuse is thrown directly on the grate, do not need much stoking.

At first sight, it would seem that refuse charged direct from cart to cell without intermediate handling should prove most sanitary and economical, yet the disadvantages of this method are many. For any particular case, a study of local conditions will determine the best system to be used.

Clinkering.—Clinkering is perhaps the most trying work in connection with the operation of a destructor. A mass of hot slag must be broken up by long bars, tipped into a wheel-barrow or other conveyance, and removed while in a highly heated condition. The work is performed by hand labor opposite the open doors of a highly heated furnace. There are various methods of conveying clinker, as by wheel-barrows, by cars on rails, or by skips running on an over-head rail. When cars or mono-railways are used, the storage room is limited, and the place where the material is deposited must be cleared at intervals; for this reason, the system has been abandoned in favor of wheel-barrows at many plants.

Various mechanical devices, such as tipping grates, etc., have been tried in order to lessen the work of clinkering, but, up to the present time, all have failed. At Westmount, in Canada, the destructor site was well adapted for a clinker pit, whereby clinker, instead of being removed in barrows or cars while hot, is dropped through a trap-door in front of the furnace to a lower level, where it is allowed to cool. This is a decided advance over the usual practice. A further improvement might be made at Westmount by enclosing the pit and utilizing the heat contained in the hot clinker for raising the temperature of air for combustion.

Character of Clinker.—As a general rule, the clinker in sight at the various installations was found to be hard and well-burned, except where plants were carelessly operated, or where fires were rushed at some electric lighting stations. In order that clinker shall be dense and that practically all the carbon shall be oxidized, it is necessary that the clinker be exposed to a high temperature for a sufficient time to consume thoroughly all the combustible material.

General Notes on Operation.—As with other works, the method of operating a destructor may mean its success or failure. A well-de-

FIG. 4.—BATLEY COMBINED DESTRUCTOR AND ELECTRIC POWER STATION.

PLATE CVI.
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NOVEMBER, 1907.
FETHERSTON ON
REFUSE DESTRUCTION.

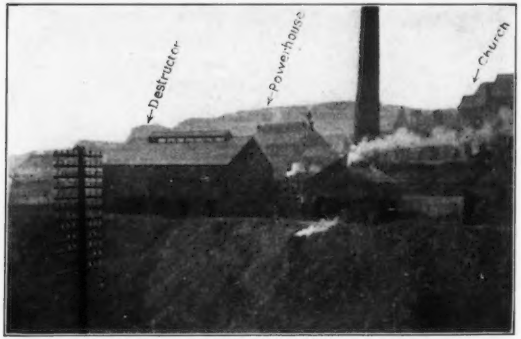


FIG. 1.—SWANSEA DESTRUCTOR AND ELECTRIC POWER HOUSE.

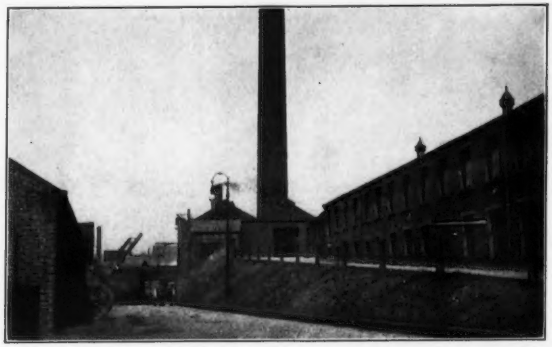


FIG. 3.—HAMMERTON STREET DESTRUCTOR WORKS, BRADFORD.

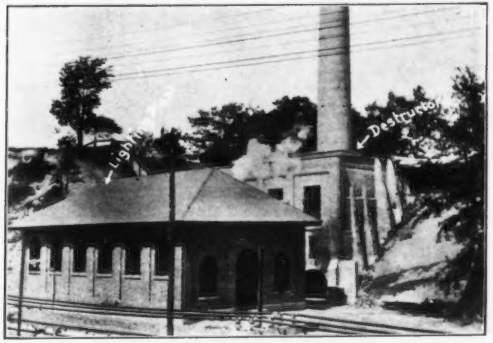


FIG. 2.—COMBINED DESTRUCTOR AND ELECTRIC LIGHTING STATION AT WESTMOUNT, CANADA.

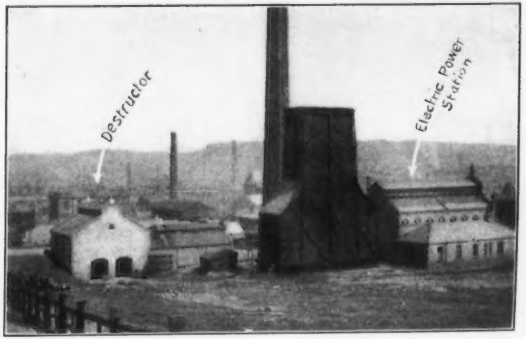


FIG. 4.—BATLEY COMBINED DESTRUCTOR AND ELECTRIC POWER STATION.

signed plant poorly operated may give rise to nuisance, whereas a poorly-designed plant efficiently operated may cause no trouble whatever. At most installations it was manifest whether or not the authorities were interested in the sanitary disposal of refuse. In poorly-operated plants, dirt, dust, and smoke were in evidence, while in efficiently-managed installations, cleanliness, order, and system were the rule. Of all destructors visited, there were few in which dust, either from the refuse on storage, or from the process of clinkering, was not a cause of inconvenience, though the trouble was usually confined to the destructor building.

The necessity for a systematic routine in the operation of refuse destructors was quite apparent, and in some of the plants the firemen worked practically by the clock. Each step in the process of feeding, stoking, or clinkering was performed regularly at stated intervals, thus tending to efficiency in management. Few self-recording devices or checks on the operations, such as steam gauges, chimney gas analysis apparatus, draft gauges, pyrometers or thermometers, were noticed at the various plants.

Temperatures.—At each destructor in operation a sight estimate of the temperature of the main flue or combustion chamber was noted, as this factor has a decided bearing upon the freedom from nuisance and the efficiency of any installation. It is of great importance, both from sanitary and economical points of view, that temperatures be regulated between a lower limit of 1 250° fahr. and a higher limit of perhaps 2 000° fahr. When the temperature is high, the gas escaping from the chimney is almost colorless, but when charging or clinkering operations are in progress, murky to dense white smoke may be apparent for a short time. As a rule, gases escaping from the destructor chimneys showed no color when compared with the black clouds emitted from the chimneys of neighboring manufacturing establishments in Great Britain.

Utilization of By-Products.—By-products resulting from the destruction of refuse, excluding the steam generated by the heated gases, consist of clinker from the grates, fine ash from the ash-pit, and flue dust from the combustion chamber or flues, besides tins, bottles and earthenware which may or may not be passed through the furnace.

Clinker.—Clinker, when burned to a hard vitreous mass, is utilized as an aggregate, mixed with cement, and made into slabs, bricks or

mortar, usually by hydraulic presses or mortar mills. If not thus utilized, it may be used for road bottoming, sidewalks, or for filling low land. The question of clinker utilization is usually decided by local conditions. Where clinker can be sold or used advantageously in making slabs, bricks, etc., machinery is usually installed, and the process results in reducing the total cost of destruction. At Worthing, on the south coast of England, clinker has been mixed with tar and used as a road pavement. The revenue derived from the sale of clinker will vary with the demand in any locality. Six municipalities report clinker sold at an average price of 42 cents per long ton.

Flue Dust.—In burning mixed refuse, some fine incombustible material finds its way into the destructor flue or dust traps, and must be removed periodically. This may have an important bearing upon the actual capacity of a destructor, as it may be necessary to shut down the plant for several days while the cleaning process is under way. The time elapsing between cleaning periods varies with the character of the material destroyed and the type of destructor. It would appear to be necessary to clean out all flues thoroughly once every 4 to 6 weeks in Great Britain, except where a special form of dust-catcher is used.

Flue dust has been used as a base for disinfecting powder.

Tins.—Refuse contains a large quantity of tinware, varying in size from food cans to boilers and wash-tubs. These articles are not usually put through the destructor, but are thrown to one side and sold in bulk or compressed by a machine into suitable bundles. At some plants, solder is melted from tins in a special furnace, and the resulting products, solder and iron, are sold to junk dealers. The revenue from the sale of tins will depend on local considerations.

Power from Refuse.—Figures for eighteen destructor tests, giving the quantity of water evaporated per pound of refuse ("from and at 212° fahr.") for periods varying from 6½ hours to one year were secured. The highest rate of evaporation was 2.66 lb. of water per pound of refuse, in a 15-hour run at a destructor in a colliery district. The lowest gave 0.88 lb. of water per pound of material, in a test of 11½ days, with refuse containing a large proportion of night-soil. The average evaporation in eighteen modern destructor tests amounted to 1.62 lb. of water per pound of refuse. In all the foregoing figures the water evaporated is a gross amount, and in order to obtain the

FIG. 2.—CLINKERING FLOOR AND DESTRUCTOR UNITS AT KINGS NORTON.

FIG. 4.—CLINKER RAILWAY AND YARD AT SUNBRIDGE ROAD DESTRUCTOR, BRADFORD.

PLATE CVII.
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FETHERSTON ON
REFUSE DESTRUCTION.



FIG. 1.—CLINKER CAR, BROMLEY.



FIG. 3.—CLINKER YARD AT KETTERING, WITH HOUSES ADJOINING DESTRUCTOR BUILDING.



FIG. 2.—CLINKERING FLOOR AND DESTRUCTOR UNITS AT KINGS NORTON.

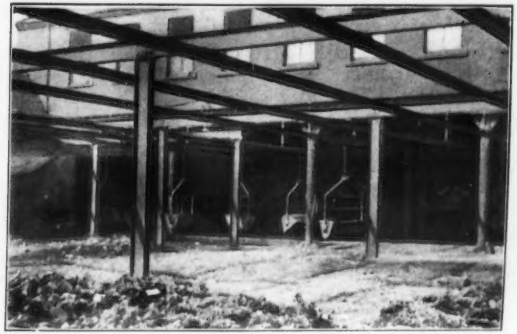


FIG. 4.—CLINKER RAILWAY AND YARD AT SUNBRIDGE ROAD DESTRUCTOR, BRADFORD.

net useful steam produced for power purposes it is necessary to deduct for forced draft apparatus. It appears, from the figures quoted, that, in a district where coal is abundant and cheap, it is possible to evaporate about 2.5 lb. of water per pound of refuse, while in other districts, distant from coal fields, destructors are capable of producing an evaporation of about 1.5 lb. per pound of refuse.

A test of a refuse destructor for a few hours hardly gives a safe figure upon which to base conclusions on power production, as the material may vary in character and calorific value with the season of the year. It is of interest to note in Table 10 that the destructor at Westmount, Canada, evaporated 1.36 lb. of water per pound of refuse in a test run of 8½ hours on May 2d, 1906. The refuse on storage at Westmount in August, 1906, was much drier, and contained a larger proportion of rubbish and ashes than the material for a similar period in Richmond Borough.

Deductions.

From data and observations made upon the various destructors, the following deductions were made:

Nuisances or Possible Cause of Complaint.—This heading means that, of the plants examined, some might, if situated in a critical position, give rise to complaints by inhabitants of the neighborhood. There is no intention of condemning any installations on the score of nuisance, as no doubt any destructor which had proved objectionable would have been closed by legal procedure.

It is possible that, of the forty installations, nine might cause complaint through the escape of unconsumed gases, poor operation of plant, or bad design.

Objectionable Features.—At the forty destructors an objectionable feature common to all was that due to the escape of dust, either from the refuse on storage, from the clinkering operations, or during the removal of flue dust. This dust, unless it escapes through the chimney, becomes a nuisance which affects only the workers about the plant, and anything that may be done to minimize it will mean a decided advance over present practice.

At sixteen plants, smoke or unconsumed gases were escaping through feeding ports, stoking or clinkering doors.

The system of storing refuse at six installations was objectionable because the firemen were obliged to work in the material when charg-

ing. At six plants the working space was cramped, and there was a lack of light and air, causing discomfort to the men. At two destructors the method of feeding refuse was objectionable because of complicated mechanical devices. At only two out of the forty plants were unconsumed particles of organic matter noted in the clinker. This was undoubtedly due to lack of efficient operation, or negligence on the part of the firemen.

Commendable Features.—Summing up the commendable features of the different installations, it may be said that practically every plant had some feature which would call for approval. In general, all the destructors were well constructed and designed for hard service. The buildings were usually of brick, substantial, and in some cases of attractive appearance. With but one exception, all the destructors were disposing of refuse without the use of additional fuel, and in the case noted, coal was used only during wet periods in summer.

Temperatures were generally sufficiently high to prevent the escape of unconsumed gases. Steam raising was practiced at all but two of the plants, and the amount of power produced had an important bearing on the economy of the process. Clinker, resulting from the burning of refuse, was sold or utilized for different purposes, tending to further economy in operation, while flue dust and tins were utilized.

Mixed-refuse destruction, whereby waste material discarded by householders is disposed of without nuisance and the resulting by-products are turned to useful purposes, would seem to be an ideal system. Certainly, in so far as sanitary disposal is concerned, mixed-refuse destruction, efficiently conducted, should cause no trouble if the material be of fair quality. While it is not possible at the present time to do more than estimate the cost of such a method in the vicinity of New York, it would appear that mixed-refuse destruction should not cost much more than garbage cremation in Richmond Borough, while the sanitary advantages accruing would more than compensate for any slight excess in cost.

Recommendations for a Mixed-Refuse Destructor Installation in the Borough of Richmond, West New Brighton District.

In view of the local experiments and experience gained abroad, the details of which are partially recorded herein, the writer recommended for the first installation at West New Brighton, in the Borough of Richmond:

FIG. 1.—WOOLWICH DESTRUCTOR YARD. PILES OF CLINKER BRICK.

FIG. 2.—MORTAR MILLS AT SUNBRIDGE ROAD PLANT, BRADFORD.

FIG. 3.—YARD AT WALTHAMSTOW, WITH PILES OF SLABS MADE FROM CLINKER.

FIG. 4.—CHIMNEY AT WESTMOUNT, WITH DESTRUCTOR IN OPERATION.

1.—A hand-fed destructor charged at the back of the furnace and clinkering on the opposite side or front of the furnace.

2.—That refuse be stored in a bin or hopper with a door or curtain to control and prevent the escape of dust into the destructor room while the hopper is being filled.

3.—That refuse be dumped into the bin or hopper behind closed doors; and that the refuse storage room be separated from the destructor portion of the building.

4.—That heated air be required for the combustion of refuse.

5.—That a water-tube boiler be specified.

6.—That steam-jet blowers, or fan-draft, or both, be provided so that the advantage of either may be determined.

7.—That the air for forced draft be drawn from the upper portion of the tipping-room and feeding or clinkering-room, so that positive ventilation may be secured.

8.—That the clinkering process be arranged so that hot clinker is dropped into a pit and the heat from the clinker is utilized in raising the temperature of the air for combustion.

9.—That ample working space, light, and air be provided in the building, and the plant be located so as to cause no trouble from escaping dust.

10.—That a suitable mess-room, bath and toilet-room be provided, for the comfort of the men employed.

11.—That the exterior of the plant be made attractive in appearance.

Contracts have been entered into with Messrs. Heenan and Froude, Ltd., for the erection of a 60-ton destructor, and with McHarg-Barton Company for the erection of the building, chimney, etc., at West New Brighton. The plant will probably be in working order before the close of 1907, and later, the writer hopes to present and compare the actual results with the preliminary studies herein outlined.

In conclusion, the writer desires to acknowledge his indebtedness to the Hon. George Cromwell, President of the Borough of Richmond, for his interest and encouragement; to Louis L. Tribus, M. Am. Soc. C. E., Consulting Engineer to the Borough President, for advice and support; to B. F. Welton, Assoc. M. Am. Soc. C. E., for his interest in the calorific tests, and for many valuable suggestions; to George Wood, Assoc. M. Am. Soc. C. E., for assistance on different portions

of the work; to the representatives of the different firms engaged in destructor building, particularly W. F. Goodrich, Assoc. M. Inst. M. E., Frank Rudder, Assoc. M. Inst. M. E., and George Watson, Assoc. M. Inst. C. E., also to the various municipal engineers, surveyors, superintendents, and managers of the British destructors examined, for their courtesy and assistance.

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PAPERS AND DISCUSSIONS.

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ROTATING SCREEN OF POWER CANAL, SALT RIVER PROJECT.*

By F. Teichman, M. Am. Soc. C. E.

One feature of the Salt River Project, Arizona, United States Reclamation Service, is a power canal, 19 miles long, having a capacity of 250 cu. ft. per sec., and 240 ft. head. The power developed will eventually be used mainly in pumping for irrigation in the Phœnix Valley. At present the power is used for the construction of the reservoir dam across the Salt River Cañon, which includes the operation of a cement mill. The power is developed in turbine wheels with guide-buckets adjusted by the governor.

The water of the canal carries much sediment, and also a great deal of grass, sticks, etc., especially at times of heavy rains. These floating bodies are likely to lodge in the narrow end of the guide-buckets, and it may occur (as it has occurred) that, if these bodies are not kept out, the governor, in attempting to close the buckets at moments of small demand of power, will break the bucket which is blocked, and such breakage may be followed (and was followed) by breakage in the runner of the turbine.

To avoid such accidents it has become necessary to send the water of the power canal through a screen, naturally located at the penstock.

* This paper will not be presented at any meeting, but written communications on the subject are invited for publication with it in *Transactions*.

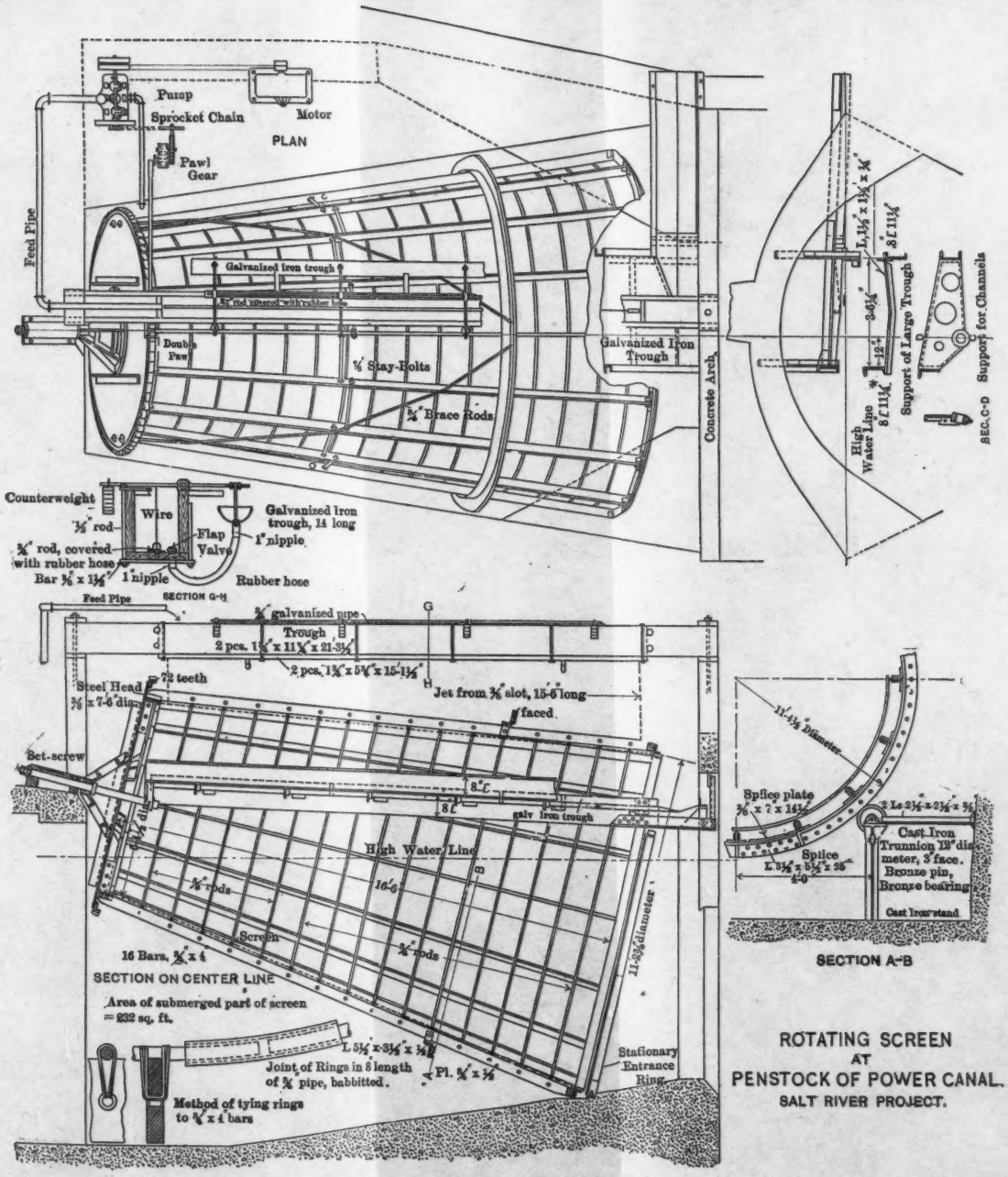
This screen is supposedly of a novel design, and, having proven successful in operation, it is thought that a short description may be of interest.

The screen has the form of a truncated cone, the water entering the cone at the base. The axis of the cone is at an inclination of 1 : 4. The cone is made to rotate slowly around its axis. To the entrance ring of the cone is fitted (with a small clearance of only $\frac{1}{4}$ in.) the stationary entrance ring. The screen of the cone is made of No. 18 galvanized wire, $\frac{1}{2}$-in. mesh, and is supported by circular rods ($\frac{5}{8}$ and $\frac{3}{4}$ in. in diameter) which in their turn are supported by sixteen $\frac{3}{4}$ by 4-in. bars, riveted to the steel head of the drum at one end, and to the entrance ring at the other. At a point about two-sevenths of their length from the entrance ring the sixteen bars are connected and supported by the trunnion ring. Between the trunnion ring and the steel head these bars are connected by $\frac{3}{4}$-in. stay-bolts. To the steel head is riveted a center casting, bored for a stationary shaft, 3 in. in diameter, held in a cast-iron shaft support. The structure of the screen, therefore, is supported by this 3-in. shaft and by two trunnions in the plane of the trunnion ring. To the steel head are bolted the segments of a cast-iron ratchet ring of 72 teeth, and a pawl, actuated by a crank-pin, worm-wheel, worm and motor, propels the screen, which makes a complete turn in about 1 hour.

The extension of the 3-in. shaft in the interior of the drum, and a concrete arch over the canal about 16 in. from the drum, support, in the interior of the drum, two 8-in. channels, slightly inclined, on which rests a galvanized-iron trough, $3\frac{1}{2}$ ft. wide and $16\frac{1}{2}$ ft. long, that terminates in a side trough. The motor which turns the screen also pumps water into a horizontal trough above the screen and centrally above the interior $3\frac{1}{2}$-ft. trough. At intervals the upper trough opens automatically, and the water it contains is sprayed over the screen and into the interior trough, carrying with it any material which has lodged on the inner surface of the screen. Material which does not adhere to the screen is lifted by blades attached to the interior of the screen, and dropped into the interior trough. The wash-water carries the screenings through the side trough over the edge of the canal.

The area of the submerged screen is 232 sq. ft. with the canal discharging 250 cu. ft. per sec. The screen would safely stand a difference in level of the water, inside and outside, of 4 ft., which may possibly occur during the first heavy rains of the season.

PLATE CIX.
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TEICHMAN ON
ROTATING SCREEN ON POWER CANAL.



ROTATING SCREEN
AT
PENSTOCK OF POWER CANAL.
SALT RIVER PROJECT.

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REINFORCED CONCRETE TOWERS.

Discussion.*

By R. D. Coombs, Assoc. M. Am. Soc. C. E.

Mr. Coombs.

R. D. Coombs, Assoc. M. Am. Soc. C. E. (by letter).—The author states that "the greatest wind pressures in that part of the country have never exceeded an average of 30 lb. per sq. ft. on large areas." While the writer is very ready to admit the probability of this statement, he would inquire whether the author has any data on recorded velocities in the locality mentioned, as the wind pressure used would correspond approximately to a velocity of 102 miles per hour.

It is not perhaps a part of the immediate subject of the paper, but it would be of interest to know the working stresses and factors of safety allowed in the span wires, insulators and other connections.

The author's assumption that all wires may break at once, at their ultimate tension, seems to the writer to be entirely unwarranted. Such an accident could only occur from:

First.—Some object striking the wires. This is very unlikely at the altitude given, and is practically impossible on account of the different planes in which the wires lie.

Second.—By the wires breaking under ice and wind loads. If the factor assumed for the wires is low enough, this is possible, though the breaking of one wire would in all likelihood jar the ice from the adjacent wires.

It seems probable that, theoretically at least, the factor of safety assumed for the tower is greater than that of the individual connections of the wires to the glass insulators. In this case the insulators or cross-arms would be torn off before the tower received the full load assumed in Case 3.

* This discussion (of the paper by D. W. Krellwitz, Jun. Am. Soc. C. E., printed in *Proceedings* for August, 1907), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

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COMPARISON OF RAINFALL AND RUN-OFF IN THE NORTHEASTERN UNITED STATES.

Discussion.*

By Messrs. J. C. Stevens, M. O. Leighton and F. H. Newell.

Mr. Stevens. J. C. Stevens,† Esq. (by letter).—It is very gratifying indeed to see the subject of the relation of rainfall to run-off treated so comprehensively and in such a systematic manner as in Mr. Hoyt's very timely paper. It is to be hoped that other sections of the country will speedily be taken up in a similar manner, and that all available data will be presented. Until this is done, it is doubtful if the engineering profession will come to a full realization of the almost utter futility of predicting the behavior of streams from precipitation records. Thus far, the only law which has been discovered is that a high rainfall produces a high run-off, and a low rainfall a correspondingly low run-off. "High" and "low," and "more" and "less" are about as concrete terms as one dare apply to this relation. This is not at all surprising when one considers the many factors that must be taken into account, and of which absolutely nothing is known. There is not even a notation which can express the relative values of such factors as soil conditions, topography, forestation, etc., in respect to which every drainage basin is different, but is greatly affected thereby. Taking long periods of time, a large number of well-distributed precipitation stations and reliable run-off data, it is sometimes possible to show a rather poorly defined relation, but to attempt any determination of the rate of flow, or a quantitative determination for short intervals of time, is almost absurd. Moreover, in every relation thus far determined there are always certain inconsistencies which perhaps are not

* Continued from October, 1907, *Proceedings*.

† District Hydrographer, U. S. Geol. Survey, for Washington and Oregon.

without explanation when once recognized, but their causes are so obscure as never to have warranted their prediction. In almost every Western State may be found monuments to some engineer's (not infrequently county surveyor's) misguided views on this question, in the shape of irrigation projects involved in endless litigation and expense, wholly abandoned, or necessarily abridged on account of the non-fulfillment of the predicted behavior of a stream. Mr. Stevens

Until F. H. Newell, M. Am. Soc. C. E., Director of the United States Reclamation Service, in the early Eighties, devised the method now in use of calibrating or rating a favorable cross-section of a stream by current-meter measurements, there was no inexpensive method of obtaining run-off. Since that time the method has been improved and systematized, until to-day the records of stream flow obtained by the United States Geological Survey are generally accepted as being authentic and reliable as far as it is possible to obtain them with a rational expenditure of time and money. In the West an engineer's office is incomplete without a current meter, and the methods of making measurements and preparing the data developed in the Government service are largely followed by those engineers in their private practice.

The subject of hydrography is perhaps as completely a scientific study in approximations as any with which the engineering profession has to deal. The absolute accuracy attainable in any particular case depends wholly on the amount of funds available, while the degree of accuracy required depends upon the use the data are to serve. Rarely will a subsequent variation of 10 or 15% from the basic data used prior to construction involve a plant in litigation or necessitate material alterations, while often a more liberal allowance is permissible. The demand upon the Geological Survey for run-off data all over the United States has made it necessary to include as many streams as possible in the investigations. In view of this fact it has been impracticable to adopt ultra-refined and expensive methods for general use, as their adoption would not be consistent with a rational expenditure of time and money.

For example, in the Columbia River District (Oregon and Washington), in 1906, the United States Geological Survey maintained 86 regular gauging stations where rating curves were developed by current meter. At these stations 719 discharge measurements were made, resulting in the publication of 753 monthly values of run-off. This was done at a total cost of $10 974, a cost of $127.60 per station, or only $14.60 per "monthly mean." Where conditions were favorable, the published results are probably within 10 or 12% of the truth, at others the results are approximate, while, at some, estimates were impossible. If accuracy had been the only essential, and results within 4 or 5% had been demanded, the entire appropriation would have been required for two or three stations, which would have defeated

Mr. Stevens. the entire purpose of the organization, which is that of benefiting the greatest number.

It seldom happens that the mean run-off of a stream will satisfy the engineer's demand for data, yet this is the only quantity determinable with any show of reason from precipitation records. Irrigation, municipal supply, and particularly water-power development require a knowledge of the time distribution of the various rates of flow. But it must be conceded that this feature from rainfall alone is wholly indeterminate. A single example will suffice. In Nebraska the Republican River has a drainage area of 22 000 sq. miles, and receives a mean annual rainfall of 22.12 in. The Loup River, with a drainage area of 13 540 sq. miles, receives a mean annual rainfall of 22.70 in. Winter records of run-off are not available, but 10-year means for the period from April to October, inclusive, show that the Loup discharges nearly 10% of the rainfall during that period while the Republican discharges less than 2% of the precipitation during the same time. These two river systems exist nearly side by side under practically the same climatic conditions. Neither area is forested, and the topography of each is similar. The difference in discharge is due to the difference in soil and other geologic features; yet it would have been impossible for anyone to have predicted this difference. It would have been the easiest matter in the world to have made an error of 500% in the mean open-season run-off of the Republican River, and yet this mean run-off is the only quantity susceptible of rational determination from rainfall records. Any attempt to obtain a minimum rate of flow in any other manner than by actual gaugings would be wholly absurd, for, notwithstanding the fact that the topography, climatic conditions and rainfall are practically the same for the two areas, the minimum rate of flow of the Loup River is about 1 000 cu. ft. per sec., while the Republican goes entirely dry.

Since, then, it must be admitted that the essential part of run-off data is wholly indeterminate, and that only mean annual values are at all possible from records of rainfall, is it not better to depend wholly on gaugings, especially when results sufficiently accurate for all practical purposes are obtained at such reasonable expense?

Mr. Leighton. M. O. LEIGHTON,* ASSOC. M. AM. SOC. C. E. (by letter).—The criticisms and suggestions that have appeared in response to Mr. Hoyt's paper are heartily welcomed by those who are responsible for the conduct of the investigations of the Geological Survey on the water supply resources of the United States. It is somewhat disappointing that some of the members who, in the past, have made very helpful verbal criticisms have not transmitted the same to the Society for publication in connection with this paper. Some of the criticisms that have been recorded will be utilized by the Geological Survey at

* Chief Hydrographer, U. S. Geological Survey.

once. It is well known that those who give exclusive attention to the details of any subject frequently fail to take a position far enough away to enable them to get a good perspective of the whole field, whereas those on the outside fail to take in much more than the broad perspective. This condition is made apparent in some of the discussion upon this paper, but more especially by the criticisms that have been received in times past from eminently qualified engineers. Therefore, it is only by taking into consideration both the nearer and the broader views that it can be hoped to bring the work up to its maximum efficiency. Mr. Leighton

There is no derogation in the statement that the majority of eminently qualified engineers have wondrously erroneous ideas concerning the controlling conditions in river-flow measurement. This is not surprising, because the practical measurement of stream flow involves specialization, which the engineer in broader practice cannot profitably keep in mind. This explains why the Geological Survey has received advice from unquestionably high sources which has revealed an almost complete lack of information concerning even the mechanical details of practical river-flow measurement. It is not uncommon to see reports, emanating from such sources, in which the run-off data have been refined to the third and fourth decimal place, while the methods of gauging the rivers in question have unquestionably been inaccurate by 5 and sometimes even 10 per cent. The Survey has seen engineers insist upon gauge readings down to hundredths of an inch when the chains with which the measurements were made would vary several hundredths within the ordinary range of temperature. Also, engineers have insisted upon minute accuracy in stream gauging, when, in the practical installation of power appliances, it is not possible to approach within a wide margin of such accuracy. Such incidents are to be expected, and therefore no complaint is made concerning them, and the statements are inserted here merely to call attention to the tendency.

Several of those who have taken part in the discussion have called attention to the fact that the run-off data presented in Mr. Hoyt's tables apply to so wide an area that complex conditions are presented which compensate and counteract each other and thereby obscure the real factors affecting the run-off. No one appreciates this better than Mr. Hoyt and the writer, but they are obliged to face the condition that in drawing conclusions from small drainage areas they merely accentuate the errors arising from unequal distribution of rainfall and of the effect produced on run-off by variable conditions of the land surfaces. Messrs. Frankenfield and Henry state very truly: "It is not advisable to draw hard and fast conclusions from either short periods of time or for small areas." Farther on, they say:

"It is obvious that the manner in which the rain falls, whether as a steady rain of moderate intensity, or as a heavy dash of great in-

Mr. Leighton.

tensity, is of much importance in determining the relation between rainfall and run-off."

Now, it appears to the writer that the fact that Mr. Hoyt's data cover wide areas of drainage is, in a way, a distinct advantage, because local errors on either side of the line of accuracy are thereby compensated. Of course, this would not be true if there were accurate measurement of rainfall, representative of these small areas, but this would be impossible under the present appropriation of the Weather Bureau, and therefore it has been the experience of the Geological Survey that it is far nearer the truth to consider the matters over a broad area, in which local inaccuracies of reading and peculiarities of condition are merged.

There is no contention that the methods and plans of work used by the Survey are the best that could be instituted. It is freely admitted that the country would profit by a minute and detailed study of the subject on all drainage areas, large and small; but, this is impossible of accomplishment with the funds at the disposal of the Survey. The practical question, then, is as follows: Given a sum of money not sufficient to carry on the work in an ideal manner over all the country, what is the best use that can be made of it? Shall it be expended on a minute study of a few streams whereby results may be secured which shall be ideal for those particular streams, but not necessarily applicable to others; or shall the endeavor be made to secure with reasonable accuracy—as reasonable at least as the present practical demands of water development require—a system of useful data for the entire country? Take any river that has been studied by the Geological Survey, and the amount of money that has been expended in such study: To make an investigation that would conform to the ideas of some of the critics would require from twenty to thirty times the amount of money actually expended. Assume, now, that this detailed work has been accomplished, and place it side by side with that which the Survey has actually performed. The former is better, of course. It satisfies the demands of precision and gives to the engineer who has performed the work, or to the one who uses it, the comfortable and much-to-be-desired feeling of sufficiency. But, applying both sets of results to an actual power installation, of how much more value is the one than the other? Does the one enable the engineer to adjust the capacity of his wheel unit or the size of his proposed storage reservoir by a degree of efficiency that is commensurable with the difference in the cost of the work? The Survey, after studying the matter for about fifteen years, believes not.

There is another and very practical consideration in connection with the policy in this matter which oft-times escapes the engineer in practice. It should be remembered that this work is done under National appropriation, and presumably all parts of the country must

receive an equal degree of attention. If all the money were expended on a few streams, it is clear that this exclusion of the remainder of the country must continue for a long period of years, and that no data would be available except on the small proportion that is actually under study. Therefore, is it not better to present to the entire country a series of results which can be used with satisfaction, even though they be not as good as could be desired, than it is to deprive the greater part of the country of useful results? The Survey believes it is better. Mr. Leighton.

The writer is especially glad to read the discussion by Mr. Vermeule, whom he regards as one of the foremost pioneers in this line, and whose work he has long considered with admiration. Mr. Vermeule contends that it would be better to confine the work of the Survey to a number of streams and insist upon minute accuracy. There is no doubt that, if this were done, he is correct in his statement that it would do far more to "reduce hydrology to a science." In making this statement, Mr. Vermeule evidently loses sight of the fact that under the present appropriations of the Federal Government the object of the work cannot be to reduce hydrology to a science, but, on the contrary, to give to the people of the United States reasonably accurate information concerning stream-flow so that they will have something upon which to work, where before they had nothing. However praiseworthy his plan may be, it is futile to consider it with an appropriation which in the past two years has been reduced one-half.

An important matter which should be brought out in connection with Mr. Vermeule's description of his study of the relation between rainfall and run-off is his use of evaporation records. He states:

"Evaporation obeys well-known laws which have been the subject of much study and investigation, so that there is much at hand on which to base a reasonable method of computing it."

Recent, but yet unpublished, work of the United States Weather Bureau has shown that our ideas of the laws governing evaporation and the methods of estimating it are so much at variance with the truth as to make it extremely doubtful whether any of our previous work on this subject is worthy of consideration. The Weather Bureau, assisted by the United States Reclamation Service and the United States Geological Survey, is planning to devote a large amount of time and money to the most extensive investigation of evaporation that has ever been made, the seat of the experiments being the Salton Basin, in Southern California, which, as everyone knows, was recently submerged by reason of a crevasse in the Lower Colorado River. In planning for this work, it was found necessary to investigate methods, and the entire past season has been devoted to this, with results that throw doubt on nearly every feature of our past studies of evaporation. In fact, it is necessary to start work in the Salton

Mr. Leighton.

Basin as though studies of this character constituted a new and untried field. Taking this into consideration, in connection with the indisputable facts concerning present inaccuracies in rainfall estimates, it is difficult to appreciate how a calculation of run-off with these two factors can be as useful as the present methods of the Geological Survey.

One word more, with regard to criticisms that have been made concerning specific stations maintained by the Survey: The fact that the Survey maintains and publishes records of any station does not commit it to any expression of belief in the accuracy of those records. It is not always possible to determine beforehand how good the records from any station may be. Sometimes it requires a full year to show whether a station is or is not worth the maintenance. In case such a station is found to be poor, the results are published merely for what they are worth, and it is the aim to give such an interpretation of them in the reports of the Survey. Other stations are established in places where it is known that the records will not be first-class, but where there is a strong demand for the best that can be produced. Strange as it may seem to those who have never gone into the details of river-station maintenance, there are many streams in the United States along the entire courses of which there is not a permanent section suitable for accurate work. The only thing that can be done under such circumstances is to produce the best possible with the funds available. With this explanation it is confidently hoped that some of those who have had occasion to criticize the Survey for the maintenance of certain stations will take all the facts into consideration, and will not grade the entire efficiency of the service on the basis of such conditions.

Mr. Newell.

F. H. NEWELL,* M. AM. SOC. C. E. (by letter).—With reference to the discussion on rainfall and stream flow, there is one statement made by Mr. Thaddeus Merriman which should not go without some challenge. He states:

"In view of the differences between the results of the gaugings set forth in this paper, when compared with other and reliable long-term gaugings on other streams, and after having made careful allowances for the differences due to variable conditions on the water-sheds themselves, the speaker is of the opinion that there is sufficient evidence to indicate that the results for the run-off shown in this paper are uniformly too large, and that the discrepancy is approximately 10 per cent."

After going over the line of reasoning indicated in this statement, the writer is unable to agree with the generalization, as it apparently ignores the results of experience of many men who have devoted the best part of their lives to the building up of this work. Great care

* Director, U. S. Reclamation Service.

has been taken in securing the highest obtainable accuracy, compatible with the necessity of having, at small cost, data from widely scattered rivers. Several of the best mechanicians of the country have contributed in the effort to perfect the devices for measuring the velocity of the water. These devices have been checked again and again against other methods of obtaining the rate of flow. It is certainly a surprise to this large group of well-trained men to be told that, in spite of the many precautions taken, the results are uniformly 10% too large. Mr. Newell.

Without entering into the details of the tests which have been made, in various parts of the country, of different methods and devices used in checking the results, it is sufficient at this time to state that, among the large body of experienced men who have devoted years to work of this character, there will be found no general admission that it is in error to this degree.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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REINFORCED CONCRETE PIPE FOR CARRYING WATER UNDER PRESSURE.

Discussion.*

BY MESSRS. ERNST F. JONSON AND R. W. LESLEY.

Mr. Jonson.

ERNST F. JONSON, ASSOC. M. AM. SOC. C. E. (by letter).—There is one point in Mr. Smith's interesting and timely paper which stands out as a possible problem to be solved in future attempts to build concrete pipes, namely, the fact that these pipes cracked both longitudinally and transversely.

If the water of Salt River had not contained considerable sediment, the cracking of the pipes might have been a serious matter. In many cases it might be necessary to design concrete pipes in such a way that they would not crack, partly on account of the excessive leakage due to cracks, and partly on account of the uncertainty about the durability of the reinforcement where it is intersected by cracks.

Longitudinal cracks are probably due to two principal causes:

1.—Shrinkage in the concrete, due to dryness while setting. This shrinkage causes an initial tension in the concrete, resisted by an initial compression in the steel. This tension is an addition to the stress produced by the hydrostatic pressure, so that the pipe will crack at a lower pressure than if no shrinkage had taken place.

2.—A strain in the reinforcement greater than that corresponding to the ultimate tensile strength of the concrete.

Cracks of the first kind might be prevented by keeping the concrete thoroughly wet; those of the second kind by using a very low unit stress on the reinforcement.

*Continued from October, 1907, *Proceedings*.

Mr. Jonson.

Pipes constructed on the foregoing principle might have walls of considerable thickness: First, because the concrete supplies the required tensile strength more cheaply than steel, when only about one-tenth of the safe tensile strength of the latter can be utilized; second, because the leakage through concrete decreases as the thickness increases; and third, if the concrete is not to crack, there is no objection to a considerable thickness.

The quantity of reinforcement in this case may be greatly reduced, leaving only enough to prevent failure in case the concrete should crack. For this purpose the steel might be strained up to 16 000 lb. per sq. in., or even higher.

Pipes designed on this basis, however, would not be economical for greater pressures than about 60 lb. per sq. in., which corresponds to a head of about 150 ft. When the concrete becomes too thick, in relation to the diameter of the pipe, any addition to the thickness adds very little to the strength of the pipe, because the stress decreases very rapidly toward the outside.

Transverse cracks, the author states, appeared in those parts of the pipe which were built in warm weather. They were evidently due, therefore, principally to temperature contraction. Such cracks might be avoided by leaving open contraction joints to be filled with grout in cool weather.

With regard to Table 2, the writer would make the following suggestions:

Instead of giving the leakage for the entire pipe, it probably would have been better to give the average leakage per unit of length, thus making possible an immediate comparison between the various pipes.

Instead of giving the head at the lowest point of the pipe, it would have been better to give the average head for the entire filled portion of the pipe. The leakage is a function of this average head more directly than of the head at the lowest point.

It would have been desirable to know the hour, as well as the day, when the tests were made.

It would have been interesting, also, to know the temperature of the water during the tests, as this affects the leakage on account of the variations in viscosity.

An additional column, giving the leakage per unit of length divided by the average head, would also have been of value, as showing more clearly the variation in the permeability of the concrete. The leakage may be assumed to be proportional to the head, except in the case of large cracks.

Mr. Lesley.

R. W. Lesley, Assoc. Am. Soc. C. E.—The author does not state the reason for constructing the pipe in the particular manner in which it was built. In Europe, for similar purposes, conduits of similar

Mr. Lesley. capacity have been built in sections. This form of construction is by no means new, for the "Bordenave" system was used in the water supply of Venice nearly twenty-five years ago. Recently, the scientific papers seem to be quite full of descriptions of the construction of water systems with concrete pipes built according to some of the methods in use in France.

Mr. Arthur E. Collins, City Engineer of Norwich, England, who visited France to investigate the "Bonna" system of concrete pipe, for pressures up to 300 ft. head, which he was about to use on some 2½ miles of concrete main in his city, reports that he found pipes made under this process at Maison Alfort, in the Department of the Seine, such pipes having a length of 10 ft., an internal diameter of 2 ft. 7 in., and a thickness of wall of 2⅜ in. In Paris, he saw pipes of this system carrying working pressures of 150 ft. head, without oozing or other noticeable defects. A similar report was given on work at Nîmes, where ⅔ mile of pipe had been laid eleven years ago and was entirely satisfactory.

There is a high-pressure concrete water pipe of this character at Swansea, England.* The main is 3 600 ft. long and 19.7 in. in diameter, operating under a head of 185 ft. The pipe consists of an inner and an outer reinforcement separated by a sheet-steel tube and all embedded in a 1 : 2 mortar. The inner and outer reinforcements consist of longitudinal bins of cruciform (+) section wound by a spiral bar of the same section wired to them at every intersection. Only the outer reinforcement and the steel tube are considered in calculating the strength of the pipe, the inner reinforcement being considered as simply supporting the mortar.

In the *English Master Builders' Journal,* of October 2d, 1907, comment is also made as to the extent to which pipe consisting of cement with steel reinforcing rivals cast iron, on the Continent. It is stated in this case that more than 200 miles of such pipe were laid in Paris alone by the "Bonna" system. This pipe can be constructed up to 6 ft. in diameter, and is rapidly becoming an important rival of cast iron.

In Venice the pipes were 6 ft. in diameter and were joined to one another. They were made by standing upright a series of iron rings which were surrounded on the inside and outside by sheet iron. Around the rings was wound a spiral (or two or three spirals, according to the pressure to be sustained by the pipe), and this "hoop-skirt" (as one might call it) of circular rings or spirals wound round it then had concrete poured upon it between the two thicknesses of sheet iron. After the concrete had set, the sheet iron was removed. The pipe was then complete, and was laid in the trench in the ordinary way. This pipe was made under the "Bordenave" process, as already stated.

* *Engineering-Contracting*, of September 18th, 1907.

Mr. Lesley.

In the United States, also, a water pipe has been made by what is known as the "Phipps" system. Two concentric cylindrical shells of sheet iron are filled with a layer of cement, and another layer of cement is filled in between a removable core and the innermost sheet. These are made upright, the cement being poured between the two shells and also between the inner shell and the core. When the cement is set the core is removed, thus producing a pipe having a cement interior. These pipes have been made up to considerable sizes.

The speaker cannot state the pressures on the Venice pipe. In the articles referred to, it will be noted that pressures up to 300 ft. have been carried. In the case described by the author there may have been some reason (not mentioned by him) that made it necessary to build the pipe in the way he describes, but the various systems of concrete pipe just referred to are well known in Europe, and have been used for many years under quite high pressures.

Another point in connection with Mr. Smith's paper is the cost of the labor on the work, but, of course, this may be well explained by the distance from civilization and the difficulty of securing good workmen. The question of cement and the difficulties found with some of it may possibly be explained, as a good deal of the material seems to have been made at the Government cement works at the Roosevelt Dam, and, according to the paper, this does not seem to have been quite as satisfactory as that first used, which came from the Denver Cement Company. In view of the fact that Los Angeles, Cal., is also about to erect a cement works of its own, for the production of the material for the new water supply, it is to be hoped that the question of a municipal or Government cement works has been thoroughly studied out by that city, before undertaking this responsibility, not only in justice to the contractors who are to use the cement, but to those people whose homes may be below the dams to be constructed with the untried material.

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THE BRACING OF TRENCHES AND TUNNELS, WITH PRACTICAL FORMULAS FOR EARTH PRESSURES.

Discussion.*

BY MESSRS. HORACE J. HOWE, C. W. BIRCH-NORD, LAZARUS WHITE, E. G. HAINES, F. T. LLEWELLYN, T. KENNARD THOMSON, ERNST F. JONSON, FRANCIS L. PRUYN AND R. A. SHAILER.

Mr. Howe.

HORACE J. HOWE, M. AM. SOC. C. E. (by letter).—The result of a rest after disturbance is an important factor to be considered in earth pressures. This is true, whether it is a case of adhesion to a pile, or of adhesion to a row of sheet-piling. The effects of weather, water, frost, shocks, and vibrations must all be reckoned with.

In city work, the evils due to digging holes, or opening up ahead in order to show progress, are apt to be impressive where delay from various causes ensues, so that perhaps a job stands over winter or longer. Quick operation spares many a patient, and the thought persistently comes, with respect to attempts at formulating probabilities, that what might be accurate, allowable, and advisable for an energetic construction gang with a clear field and all obstacles, legal and official, removed, might be questionable when the above agencies have full play for a considerable time in a busy street.

The author sees fit to reverse the customary two-thirds height, of the authorities, and consequently increases the top relative to the

* This discussion (of the paper by J. C. Meem, M. Am. Soc. C. E., printed in *Proceedings* for August, 1907), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

bottom bracing, as shown in Fig. 7. This is a good thing to emphasize practically. One reason is that larger openings are thereby made; intermediates are not required; and buckets can have free swing when at full speed upward; but, owing to changes of cleavage of the earth, due to the above causes, the writer believes that the center of pressure will tend to travel downward, and the proportions indicated will not be preserved. The dimensions in Fig. 7 would be liberal for a pit of ordinary width, say 12 ft. Mr. Howe.

The writer had occasion once to watch a contractor who used 6 by 6-in. stuff throughout, to a depth of about 35 ft. About half way down, the bracing showed strain, and made this size about the limit, in his experience. Two lines of surface cars straddled the hole, and added substantially to the packing around the sheeting, as time went on.

The writer has seen long, straggly braces, propped up by verticals, where the author's sizes would not be adequate, and where diagonals to the ground were evidently needed.

Fig. 1, Plate LXX, gives a view at 70 ft. depth after the removal of plates in moist sand. Whether under air pressure, and for how long a time the exposure was made, is not stated. This quiescence indicates lack of pressure on the underside of a tunnel tube, and presumably on any similar foundation. Is it to be assumed, then, that nothing is gained by increased depth of foundation except greater compactness of soil?

The writer agrees that the use of the crown-bar system under a street leads to slumps, and trouble in general. Some years ago he observed an attempt made in a neighboring city by experienced contractors. The soil was reliable, but the work had to be taken out of their hands, in the interest of safety to the public. The arch system would possibly have been more successful.

In conclusion, the writer is constrained to quote the opinion of that great formularizer, Rankine, on earth pressure. He says:*

"The properties of earth with respect to adhesion and friction are so variable, that the engineer should never trust to tables or to information obtained from books to guide him in designing earthworks, when he has it in his power to obtain the necessary data either by observation of existing earthworks in the same stratum, or by experiments."

C. W. Birch-Nord, Jun. Am. Soc. C. E. (by letter).—Mr. Meem's principal statement regarding the location of the resultant of the lateral forces on retaining walls seems to be somewhat different from what most engineers have been accustomed to use in their calculations. Mr. Birch-Nord.

Does it seem reasonable that a material with a certain angle of repose will act in a manner so entirely different from water that it will change the location of the resultant of the lateral forces from $\frac{1}{3}h$ from the base to $\frac{1}{3}h$ from the top?

* "Civil Engineering," page 317.

Mr. Birch-Nord. Does it not seem reasonable that the maximum lateral pressure per unit should be greater near the base?

Mr. J. A. Jamieson, in his valuable paper, "Grain Pressures in Deep Bins,"* shows that the maximum lateral pressure per unit occurs near the bottom of the bins.

E. P. Goodrich, M. Am. Soc. C. E., in his paper, "Lateral Earth Pressures and Related Phenomena,"† gives results similar to those obtained by Mr. Jamieson, and he goes even so far as to prove that the resultant of the lateral forces is located between $0.38h$ and $0.40h$ from the base.

Mr. Meem illustrates his method of locating the resultant of lateral pressure by assuming two triangular-shaped pieces of ice lying on top of one another, and states that the resisting force, P, should be applied at $\frac{1}{3}h$ from the top, but, by making the experiment it will be found that the force, P, may be applied at any distance above the apex and still cause equilibrium.

There are many tangled, incomplete and different ideas regarding earth pressure and its action, and it is about time that something were done, in the line of extensive experiments, either by a Special Committee of the American Society of Civil Engineers or by some of the leading universities, in order to establish the facts in reference to this matter.

Mr. White. LAZARUS WHITE, ASSOC. M. AM. SOC. C. E. (by letter).—During the writer's connection with the work of constructing the subway through Joralemon and Fulton Streets, in Brooklyn, he has frequently discussed with Mr. Meem his theory of earth pressures, and, although at first he held more nearly to the generally accepted view of earth pressures than that advocated by Mr. Meem, he has come to believe that his general views, when applied to the pressure exerted by materials without hydraulic properties, but with at least the cohesiveness of moist sand, are more nearly true than those accepted in the design of retaining walls since the time of Rankine. However, Mr. Meem says he would not apply his methods to the designing of retaining walls.

The photographs in the paper give ocular demonstration of the fact that earth pressures do not ordinarily increase with the depth, but that, on the contrary, in undisturbed material they are almost zero at the bottom of the trench. It is with this point in view that Mr. Meem has solved so successfully numerous difficult problems in connection with the subway in Brooklyn. Along Fulton Street, in particular, a long line of buildings had to be underpinned, and the elevated railroad, trolley tracks and numerous pipes had to be supported. This work has advanced so far now, and Mr. Meem's methods

* *Transactions*, Can. Soc. C. E., Vol. XVII, p. 554; also *Engineering News*, March 10th, 1904, Vol. LI, p. 236.

† *Transactions*, Am. Soc. C. E., Vol. LIII, p. 272.

have been used on so large a scale, that it can be fairly said that his ideas and methods of sheeting have been demonstrated experimentally on a very large scale. Mr. White.

It is true, as Mr. Meem says, that sheeting and bracing used in tunnels and open excavations are usually placed by foremen in a somewhat haphazard and happy-go-lucky way. In some cases the writer has seen enormous quantities of timber used to accomplish results obtained by Mr. Meem with a much smaller quantity, designed in advance and placed carefully by his methods. In the former case, bracing foremen have been allowed to place timbers wherever they thought them necessary, with the result that the trenches were encumbered with a mass of timber which seriously handicapped the placing of steel and masonry.

It will amply repay any engineer to make careful study of Mr. Meem's paper and the methods used by him. The most severe test of his methods was at the Joralemon Street Tunnel, where the double-track subway was excavated through coarse sand, and in close proximity to various flimsy buildings, without damaging them to any serious extent. In addition, the cast-iron tubes on the Brooklyn side of the Battery Tunnels were reconstructed under his direction. Such a reconstruction is considered by the writer as a feat which has never before been attempted, but Mr. Meem's modesty prevents him from giving it the importance it deserves. There is no field of engineering where poor and slipshod methods can accomplish the waste of so much time, money and even life as that in timbering and bracing soft ground. Mr. Meem has made considerable advancement in tunneling through soft ground, and in bracing deep trenches.

E. G. Haines, Assoc. M. Am. Soc. C. E. (by letter).—This paper has proved of great interest to the writer, as he has been connected for several years with work requiring excavation in large quantities, in sheeted and open cuts, shafts, drifts, etc., and has had opportunity to observe the action of the materials under varying conditions; and, having contemplated writing a paper on the subject, he presents the substance of it now, as a discussion of Mr. Meem's paper. Mr. Haines.

Some time ago, after consulting all the available writings on the subject of earth pressure, and being unable to reconcile the results with his own observations, the writer became convinced that the common theory was erroneous, and that no practical formula could be developed by considering earth (unless either so dry or so saturated as to flow) either as a granular or as a fluid mass, but that it must be considered as a solid body, the characteristics of which it possesses.

The writer will endeavor to illustrate the result of a number of observations of "slips" or "caves," in both sheeted and open cuts, etc., and give his conclusions thereon, in the hope that they may be of some assistance in developing a practical formula for pressure.

Mr. Haines. In excavating open cuts without sheathing, with the sides nearly or quite vertical, slips frequently occur, the form of the fracture being very uniform (for the same material), and as shown by Fig. 16.

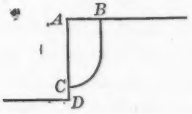


FIG. 16.

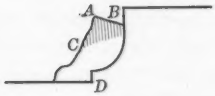


FIG. 17.

After the slide has subsided, or come to rest, it will have assumed a form such as shown by Fig. 17. The top surface, *A B*, will frequently be found inclined as shown, and quite a large volume of the material, *A B C*, quite undisturbed. The distance, *A B*, is usually about one-half *A D*, and, for any one material, keeps very closely constant.

It is very frequently noted that the toe of the fracture occurs at *C* (Fig. 16), some little height above *D*, and the writer was for some time unable to assign a reason. This will be considered later.

The plan of the slip is generally of the form shown by *A B C*, or *D B E*, in Fig. 18, while the vertical elevation of the face is as shown by Fig. 19. It may also be noted that in any material except dry sand, or in saturated ground, one may excavate to a certain depth without danger of slides; but, upon going deeper, slides are very apt to occur.



FIG. 18.



FIG. 19.

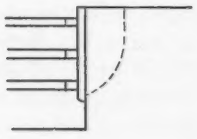


FIG. 20.

Taking next the case of a sheeted trench: It will usually be found that, for some little depth, the sheeting can be driven easily, and without evidence of much pressure. The pressure then becomes evident, and a crack appears at the surface, as shown in Fig. 20, although the line of rupture may not appear at the bottom, even if the earth is exposed below the sheeting.

Again, with sheeting driven to some depth, and kept tightly keyed and filled, a cave will often occur at the bottom, as shown by Figs. 21 and 22, if the planks are not kept well footed, and this without showing any sign of a fracture of the whole bank, at the bottom or at the surface.

Again, the surface, after the first crack (in Fig. 20), may not crack farther back, even though the excavation be continued to considerably greater depth.

In the case of a tunnel heading or drift, it is frequently found that a small drift can be driven with perfect safety; but, upon attempting to drive a larger section of the same form, in the same ma- Mr. Haines.

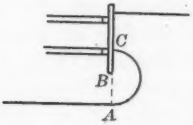


FIG. 21.

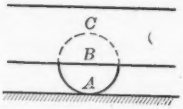


FIG. 22.

terial, falls are of frequent occurrence, and appear about as in Fig. 23.

Taking also the case of shafts or pits, it will frequently be found that a circular pit can be sunk to some little depth, without caving, in material in which a square pit or trench will cave badly, as shown by Fig. 24.

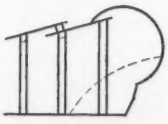


FIG. 23.

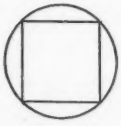


FIG. 24.

The three main classes of excavation have now been mentioned: a longitudinal trench, a horizontal drift, and a vertical pit; and, without carrying the matter further, the writer would state that in not one of these cases is there the slightest evidence of either a force similar to a hydrostatic pressure, or one similar to that required by the theory for a finely-granulated mass. After the fall occurs, other conditions remaining unchanged, no further action takes place, often for extended periods of time.

The writer has examined many falls, under all the foregoing conditions. In quite a number of them he has had occasion to take measurements, and has been impressed with one feature common to all, namely, the shape of the fracture. In nearly every case, a cross-section of the fall, in one or any direction, is in the form of a curve approximating a segment of a circle. In other words, the fractured area forms a portion of the surface of a sphere.

This fact is important. It is totally inconsistent with the theory for fluid pressure, or that for a fine granular mass; but it is perfectly consistent if the earth is considered as an elastic solid body. This assumption may properly be made, as a mass of earth in its undisturbed state possesses the same properties of cohesion, weight, tensile, compressive and shearing strength, as does a mass of sandstone, but in much less amount.

The application of this the writer will now attempt to show.

Mr. Haines. If a cube of stone, or other solid of granular structure, is submitted to compression between two parallel plane faces, it will fail, first by a shearing out of the sides, along the lines, *A B C*, Fig. 25, followed by a crushing down at *B*. If, instead of a cube, a slab is substituted, with the load applied as in Fig. 26, it will shear off from *A* to *B;* but, if the load be applied as in Fig. 27, and be free to move laterally, it will shear off from *A* to *B* as shown.

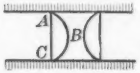


FIG. 25.

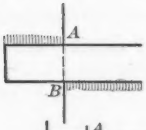


FIG. 26.

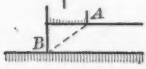


FIG. 27.

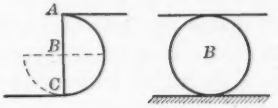


FIG. 28.

Now, this is exactly what takes place with a bank of earth, modified by the fact that such a bank must itself furnish the destructive agency, or the weight necessary to cause the shear.

It is known that the greatest area is contained within a given perimeter when it describes a circle; also, that the greatest volume is contained within a given superficial area when that area forms the surface of a sphere. Herein lies the secret of the spherical fracture. To illustrate: take a bank of earth caved as shown in Fig. 28, in section and elevation.

If D = the depth, *A C*, in feet;
W = the weight per cubic foot;
V = the volume, in cubic feet;
S = the shearing strength per square foot;
and A = the spherical surface, in square feet;
then, at the instant the cave occurs, $W\ V = A\ S$.

Now, for a sphere, $V = D^3 \frac{\pi}{6}$,

and $A = D^2 \pi$.

Therefore, the weight of the volume varies as the cube of the depth, while the area varies as the square of the depth; and, W being easily obtainable, if the value of S were known, the value of D could be found at once, and thus the depth which could be excavated without any caving of the bank. This would be of no practical value, however, as S would not remain a constant, but would change under weather and other influences, in some cases reducing to nearly zero; it is important, however, in the respect that it determines the section of the

volume causing fracture, and, consequently, the pressure against any medium designed for its support. Mr. Haines.

In case the slide is very long in proportion to its height, it is simply an extension of the spherical form, caused by continued falls, the form of the cross-section remaining unchanged. It still remains a semicircle, and explains why the crack at the top of a bank appears at a distance back equal to about one-half the depth, since the depth equals twice the radius of the curve of fracture.

In the case of an unsupported face, as in Fig. 29, the fracture does not complete the semicircle, *A B D*, but breaks out from *B* to *C*, as the distance is shorter, and, consequently, the line is one of less resistance.

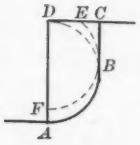


FIG. 29.

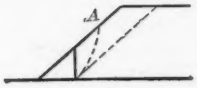


FIG. 30.

The tendency to complete the curve, however, is shown clearly in many slips by the decided overhang at the top, as at *E;* and is shown perfectly in the case of a cave at the bottom side of a sheathed trench, as in Fig. 21; the distance, *B C*, seldom being much in excess of *A B*, if the sheathing has been kept keyed tight. In short, the earth does not "fall," but shears and slides out, revolving around the point, *B*, Fig. 28; and, in an unsupported bank, the top surface will always be found on top after the slide has subsided, as was shown in Fig. 17. A cut of solid rock, if carried to sufficient depth, would act in the same manner.

A simple experiment will show the action which takes place. If, within a hemispherical cavity, there is placed a hemisphere of the same size, with its plane surface vertical (as shown again by Fig. 28), a certain pressure exerted below *B* will maintain it in its position; but, if the pressure be removed, the hemisphere will revolve until its plane surface becomes horizontal, as shown by the dotted line.

Mention has been made of the fact that the bank frequently breaks out at *F*, Fig. 29, instead of at *A*. This may be influenced by the change of the line of resistance, from *B D* to *B C*, though the writer does not now see how, but believes it to be due to the increase in the density of the material with increase of depth, and the tendency to follow the line of least resistance. It is not important, however, as the greatest area is contained within the lines, *A B C D*.

The author has presented a very simple theory, and a straight-line formula for pressure; but it appears to the writer to be defective, for the following reasons:

Mr. Haines.

First.—It assumes, in effect, a material devoid of friction, which can hardly be assumed. Even in a material bearing large quantities of water, the adjoining excavation drains the excess of water, and the bank develops a large amount of frictional resistance.

Second.—The section of the bank causing pressure is not bounded by a straight line, but by a curve, as has been shown, part or all of which is a segment of a circle.

Third.—It is based on an angle of slope for the material, which is a factor not existing in a cut, but only in a fill, and then only when freshly made. The writer has frequently cut off the base of an embankment which had a well-defined angle of slope when deposited, and, although slips sometimes occurred, they did not extend to the top of the bank, but broke out as shown in Fig. 30, at *A*. The writer will admit that, given sufficient time, the face of an excavation would assume the same slope as would the material if placed in an embankment. It is not due to any cleavage plane in the material, however, but to the action of the elements. The surface is loosened by the rain, frost, and sun, and then water, wind, and the force of gravity move the loosened material, and pile it up at the base of the bank at its frictional angle of repose, Nature simply doing, after a long time, what Man, in forming embankments, does at once.

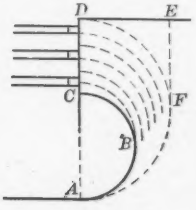


FIG. 31.

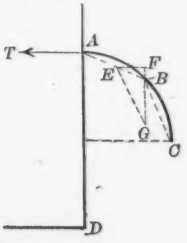


FIG. 32.

The writer recently examined a borrow-pit, on work with which he was connected fourteen years ago. The cut was about 25 ft. deep, the slope being left rough, anywhere between vertical and ¼ to 1. The material was principally sand, and the cuts of the railroad, in the same material, were sloped to 1½ to 1. Numerous slips had occurred in this bank, all showing the curved line of fracture, but a large portion of the face still stood practically intact.

It appears to the writer that the pressure against sheathing is entirely due to arch action, and that in a consideration of the curved line of fracture should be found the basis of a pressure formula.

Let Fig. 31 illustrate a sheeted cut, caved at the bottom along *A B C*. The volume, *B C D E*, forms one-half of a perfect arch with semicircular intrados, and the crown thrust is taken up by the timber-

ing and the compressive strength of the earth. This holds good for any position of the line of fracture, as shown by the dotted lines, and the arch will stand, unless the cave extend so close to the top, at *D*, that the pressure exceeds the compressive strength of the earth, or, the concentration of pressure at *B F* causes shear, or crushing of the area, *A B F*. The lines of compression must follow closely the lines of fracture, for, while the crushing value is fairly high, the value for shear is quite low, and any inclination of the compression to the fracture line would cause shear and continued falls of the material. Mr. Haines.

Considering the line of fracture to be the line of compression, the pressure at any point against the plane, *A D*, can easily be computed. This can be done graphically very quickly, as shown by Fig. 32. Let the line, *A B C*, be the center line of an arch strip of unit section, and let *L* equal its length. Also, let *W* equal the unit weight of the material. From *B* (the center of gravity of the line, *A C*) draw *B-G*, vertical, equal to *W L*, to some convenient scale. Completing the triangle of forces, *E-G* and *B-E* are equal to the resultant of the forces at *C* and *A*, respectively; and *E-F* is equal to the horizontal component of *B-E*, or, the horizontal pressure at $A = T$.

Assuming, for purposes of comparison, that $W = 1$, and solving for *T* at different heights, a series of coefficients is obtained, which, if multiplied by the actual value of *W* for any case, equals the pressure for that height. This is shown in Fig. 33, by the line, *A*, as well as the same factor for the author's method (assuming a natural slope of 1½ to 1), and the common theory for hydrostatic pressure, by the line, *C*.

The area, *D E F*, Fig. 31, however, has not yet been considered. This section, directly, cannot cause any pressure at *D*, because its area at that point is zero. Indirectly, however, it does exert a pressure along the whole height, *A D*, due to its dead weight, this pressure being zero at *A*, and a maximum at *D*. The total amount of arch thrust from this area can be found by taking *F* as a center of moments and computing the thrust at *D*. The writer believes this to be distributed, varying uniformly from *A* to *D*, and, converting its value to the form of a triangle, and adding to the line, *A*, in Fig. 33, the line, *D*, is obtained, giving the total coefficient of *W* and the unit pressure at any height.

It will be noticed that this line gives pressures about half as great as those by the author's formula, and the writer believes that these are more nearly correct. He has never seen anything to indicate the extreme pressures shown by the author's formula, and Mr. Meem states that it is seldom necessary to use timbers as large as required by that formula.

Since the value of any theory depends upon its application to different conditions, the results, by the one proposed by the writer, will

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be compared with the conditions found in practice in widely different cases.

Taking first a shaft: If the material be fairly uniform, and the shaft can be excavated to a depth equal to its clear width without falls, there is little danger of falls at greater depth, and the reason is not hard to find. Let *A B C D*, Fig. 34, be such a shaft. If a hemisphere, described on any side, be not heavy enough to cause shear over its surface, there is little danger of a larger fall (as shown by the dotted line), for it would then also have to crush a ring of the material, as at *D E*. The pressure likely to be found, then, at any depth, is due to local falls, and is equal to the arch thrust, shown on Fig. 33, for a height equal to the width of the shaft.

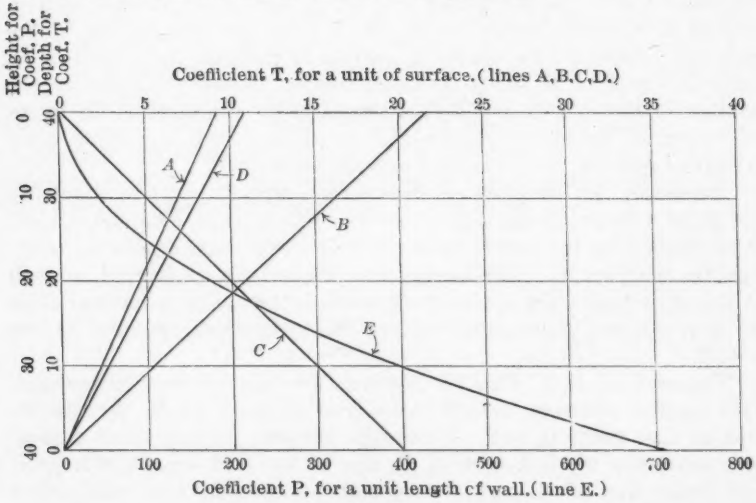


FIG. 33.

Fig. 34 also shows why a circular shaft is the safest form, as the hemisphere of dangerous weight has already been removed on each side, and the earth can fail only by the crushing of the material.

The writer, a few years ago, watched with considerable interest the excavation, in moist sand, of a well, about 8 ft. in diameter, without the use of sheathing. After the excavation had proceeded a few feet a wooden templet was placed, and an 8-in. brick lining was built to the surface. From that time forward the excavation proceeded by cutting under the templet, and the bricklaying was continued at the top, until, when last seen by the writer, a depth of 55 ft. had been reached. There was no evidence of crowding, or pressure, and the ring sunk readily, although the excavated material took a slope of about 1½ to 1. The foreman stated that he had often used this method for much greater depths.

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Taking also the case of tunnel drifts in ordinary material, as shown by Fig. 35: If the sides, only, were of solid rock, a fall might be expected, as shown by the semicircle, *A B C*. Also, if the roof, only, were of rock, a cave might be expected, as shown by *A D E*. In abandoned mine workings, where falls are of frequent occurrence, the writer has found these conditions fulfilled, the earth seldom breaking back of the supporting rock, at *A* and *C*, and the height at *B* (unless the spherical surface be broken by boulders) not exceeding one-half *A C*, even though considerable water be flowing. In the case of a drift in clear earth, however, the timbering cannot be kept in perfect contact with the earth, and after the portions, *A B C A* and *A D E A*, have moved, there remains the section, *A B D A*, without support, except its cohesive strength, and it falls.

Thus it is seen that in firm ground the section causing pressure on a drift is described, from *F* on the axis of the drift, by a semicircle, with a radius equal to one-half the sum of the height and width, and completed by two quadrants, described from *G* and *H*, with a radius equal to one-half the height. Now, as to the actual pressures: The pressure against the cap, *B C*, Fig. 36, is due to the dead weight of the volume, *A B C D*, and varies as the ordinates between the lines, *A D* and *B C*.



FIG. 34.

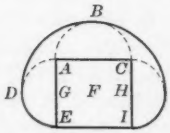


FIG. 35.

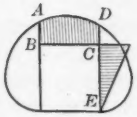


FIG. 36.

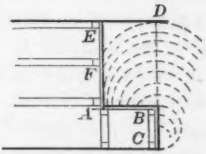


FIG. 37.

The pressure against the side, *D E*, however, does not vary as the ordinates to the curve, but is due to the arching action of the material, as shown by the line, *A*, Fig. 33; and it is probable that most of the total pressure for the height, *D E*, is concentrated against the height, *C E*, as shown.

That the pressure at *C* is far in excess of that at *E* is shown clearly in practice by the fact that it is always necessary to strut between the top of the legs of the bents (unless they be mitered, or entered into the caps), while at the bottom they rest simply on a mud-sill.

Considering next the case of open cuts: The author has mentioned the case where it may be necessary to undercut the side of a sheeted trench, as shown by Fig. 37, and the writer recently saw such a case, the work being done by the author with perfect success. After the cut had been carried to about 20 ft. in depth, it was found necessary to excavate a gallery, about 200 ft. long, 5 ft. high and 7 or 8 ft. wide, along the side of the cut at the bottom. This was done by using

Mr. Haines. poling boards from *A* to *B*, supporting them on wall-plates and posts, and by short vertical sheeting from *B* to *C*. This gallery was under a street carrying a double-track trolley line and heavy wagon traffic, and tremors from nearby elevated railroad structures could be plainly felt. The material was compact gravelly loam, with some small boulders. There was absolutely no evidence of any pressure against *B C*, the earth being exposed sometimes for several feet, and the plank placed by hand. There was some evidence of load on the poling boards from *A* to *B*, but nothing like the full weight of the material above them. There was evidence of considerable load on the posts at *A*, however, and also a considerable thrust, laterally, on the timbers, *A*, *E*, and *F*, as shown by the fact that points given on the timbers, for use in the construction, moved from 1 to 2 in. This is exactly what might be expected from the arching of the material, as, the axis of the arch being on the line, *C D*, there is both a horizontal and vertical component to the thrust against the sheeting, as shown by the curved lines of thrust.

Thus far, the writer has confined his examples to what may be termed stable material. He will now go further, and say that it applies equally well to any material.

Taking first the case of dry sand: In the work of the Atlantic Avenue Improvement, in Brooklyn, of which the writer was Resident Engineer of a division, it was necessary to excavate a trench about 1½ miles long, 35 ft. wide, and about 25 ft. deep. On each side of the cut was a line of railroad track, carrying locomotives and heavy traffic, the center of the tracks being in some cases only 6 ft. from the sheeting. On one side of the cut, 20 in. from the sheeting, there was also a 48-in. water main under pressure.

The contractor, wishing to withdraw as much of the sheeting as possible, placed it in two lengths. The top part was composed of 18 or 20-ft. planks, and the lower part was pieced out with 1¼-in. planks, set about 1 ft. in the ground at the bottom, and held at the top (from 5 to 7 ft. above) by cleats nailed to the under side of the bottom rangers. The material varied greatly, but in sections it consisted of sand so clean and fine that it filtered through the cracks in the sheeting and piled up at the bottom. A worse set of conditions could hardly be conceived, yet none of these light boards failed, nor did they show signs of great pressure, although 6 by 10-in. rangers cracked, near the top of the cut, in a number of cases. By referring to Fig. 38, the reason will be made clear. If a vessel be filled with fine sand, and an opening be made in the side, as shown at *A*, the sand will not flow out unless the height of the opening exceeds two-thirds of the thickness of the wall; but, if a larger opening be made, as at *B*, the sand will flow and pile up until its angle of slope reaches the top of the opening, and no more will then flow out. Within the vessel, the action

still goes on; the sand falls from the bottom of the arch, and piles up at the bottom, until it finally breaks out at the top. This is purely an arching action, the falling material serving to support the base of the arch and building up a new arch as it is deposited, the lines of pressure being more clearly shown by Fig. 39. Mr. Haines.

The writer traced the line of first crack, on both sides of the work just mentioned, in the block paving of the street, for nearly the entire length of the work, and the ratio of width to depth appeared to be entirely independent of the character of the material; and, although the railroad track was sometimes within and sometimes without the fractured area, the first crack appeared very closely at a distance back equal to one-half the depth of the cut.

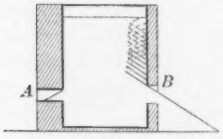


FIG. 38.

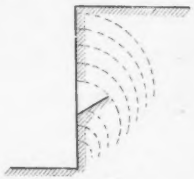


FIG. 39.

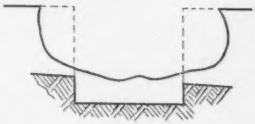


FIG. 40.

Turning now to saturated material: In the construction of a section of subway, in New York City, a trench was excavated about 45 ft. wide and 35 ft. deep, through ground which at some time had been filled into tidal water. The top surface of the ground was 7 ft. above mean high water, and the water appeared at that depth in the excavation, and constant pumping was necessary. The excavated material was so soft that it would slop out of the buckets, and the laborers had to work in rubber boots. The sheet-piling was driven by a pile driver, and the bottom 5 to 8 ft. of the cut was in rock. After the excavation was complete, a crack, about 2 in. wide, appeared at a distance back somewhat less than half the depth to the rock. It became evident that the timbering was under some stress near the top, but it would have held safely had it not been for an unfortunate accident which destroyed the timbering, and the cut caved in, on one side for about 60 ft. in length, and somewhat less on the other. The material from these slips assumed such a flat slope that the two sides met in the bottom of the cut, and piled up as shown by Fig. 40, leaving exposed a height of about 20 ft. of the cave on one side. The top overhung the face, 8 ft. below, by nearly 3 ft., notwithstanding the fact that the base of a large pile of rock was within 6 ft. of the edge, and part of the footing for a stiff-leg derrick was actually beyond the exposed face below. It was several days before all the timbers could be replaced, and the slide refilled, yet it stood in this condition. The writer had a number of measurements taken, and, all things con-

Mr. Haines. sidered, it was the finest example of the spherical fracture he has ever seen.

A mass of saturated earth closely resembles a mass of wet concrete, and Plate CX is a photograph, showing a cave in the latter material, due to insufficient bracing of the forms. The thickness of the wall was 3 ft., and the cave extended 4 ft. deep, the top being disturbed for about 2 ft. back from the form. The disturbed portion was all within the line drawn on the photograph, and the vertical face of the fracture is clearly shown at *A*. The portion marked *B* slightly overhung the fracture below. The concrete was placed quite wet, and none of it had been placed more than an hour, so that it could hardly be said to have set.

Taking, then, the design of a coffer-dam, with sheet-piling driven to some depth, as at *C*, Fig. 41 (*a*): As the water is pumped down, there is a uniformly increasing pressure against the sheet-piling, as shown by Fig. 41 (*b*). Below the level of the point, *B*, the material may be in either one or two conditions, which may be termed water filled with earth, or, earth filled with water. In the first case, the material is what is called mud; it is not a fluid, nor does it act as one. It is insoluble mineral matter, and its presence in the fluid does not increase the density of the fluid, or its hydrostatic pressure, any more than it would if the grains were widely separated, and at points away from the sheeting. The water forms a perfect film against the sheeting, the same as it would in a box filled with billiard balls; and the pressure diagram for the water extends to the bottom at *C*, as shown by the triangle, *E F G*. The volume of earth, *B C D*, also exerts a pressure against the sheeting, in the same manner as dry sand. The water leaking through the sheet-piling, or under the bottom, however, carries with it some of the earth, and tends to destroy the arch; and, unless more material be added, to allow it to rebuild itself, and the sheet-piling be kept well footed below the limits of the excavation, the arch will be entirely destroyed, and the unbalanced pressure from the other side will move the dam and cause its destruction. Thus there is, in this case, the arch pressure for the height, *B C*, added to the hydrostatic pressure, as shown by *G H I*. The amount of the pressure, however, is reduced by the buoyant effect of the water, and the value of *W* to be used with the coefficient is the difference between the weight of the water and the earth.

The second condition mentioned—that of earth filled with water—covers such material as shale, some clays, compact earth, and gravel. This material, while it passes water freely, somewhat resembles a series of screens, all made of wire of the same size, but of different mesh, the finer mesh being at the top, and increasing in size downward. This applies to a large number of materials, the finer and more compact material having been deposited at the top, and the writer



CAVE IN MASS OF WET CONCRETE, DUE TO INSUFFICIENT BRACING.

has often produced this effect artificially by a covering of clay, a canvas mat, straw and manure, chaff, etc. Mr. Haines.

In this case, the pumping tends to remove the water faster than it can enter at the surface of the earth, and prevents any hydrostatic pressure below *B*. The water-pressure diagram is shown by *A B E*, in Fig. 41 (*c*). Below the point, *B*, there is the arch pressure due to the earth, but it is also carrying the weight of the column of water, shown by *A B D J* in Fig. 41 (*a*), and, in determining the factor, *W*, to use with the coefficient, it must be included in the weight of the earth, *B C D*, in Fig. 41 (*a*). The pressure diagram, then, is completed by the triangle, *B C D*, and, if the depth of the water be very great, the pressure below *B*, for a distance, may even exceed that due to the hydrostatic pressure, as shown by the dotted line, *C F*.

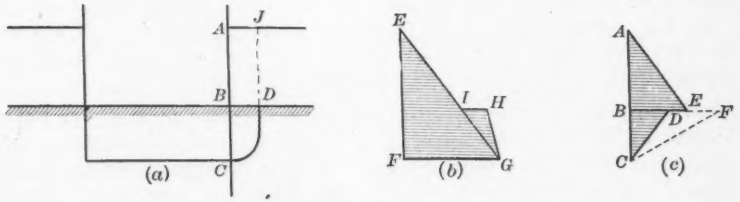


FIG. 41.

In subaqueous tunnel work, with a shield, and under air pressure, there obtains, probably, the worst set of conditions. Let Fig. 42 represent such a case. Here, there are peculiar conditions. If the air pressure is made equal to the head of water at the top of the tube, water will enter below that point, while, if the pressure be made great enough to keep out the water at the bottom, the air will escape rapidly above that point. Either of these things tends to destroy the arching effect of the earth. A common practice is to keep the pressure about equal to the head of water at the center of the tube, and allow some water to enter. This causes softening of the material, with consequent settlement, and the whole mass probably settles down along the lines, *A B C*. The excess of air pressure at the top causes erosion of the material, and "blow-outs" occur, followed by a reduction of air pressure. This reduction of pressure causes a rush of material toward the tube, and partially restores the arch just destroyed. That the disturbance is purely local is shown by the fact that a relatively small amount of clay, dumped in the water, is sufficient to close the break, and allow work to proceed which would not be the case if one considered the angle of slope at which the material would stand.

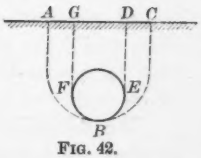


FIG. 42.

Mr. Haines. In the air chamber, the shield being a perfect arch, and also air-tight and water-tight, there is an arch of earth over the shield which is not subject to disturbance, and it probably carries most of its own weight. Were this not the case—the material at the bottom being much softened by the incoming water—the weight at the top would cause a dip to the shield which it would not be possible to control. Back of the shield, however, the rings as placed are not tight, and the air escaping at the top and the water entering at the bottom cause a continuous disturbance of the earth, and the rings probably carry a large portion of the weight, the water being taken care of by the air pressure. Back of the air locks, where the air pressure has been removed, the action of both water and earth is downward; and, as the joints are made tight, the earth becomes a perfect arch, supporting most, or all, of its own weight, and the rings are subjected simply to the hydrostatic pressure of the water which passes through the earth.

Fig. 42, then, also shows why a tube tunnel, under these conditions, fails to rise, but settles instead; for, to rise, it would not only have to raise all the material included between *D E F G*, but also shear all the material along *D-E* and *F-G;* and this factor, even in material which has been deposited at the bottom of water, is of no small amount. In short, it makes no difference whether the water is filled with earth, or the earth is filled with water; the action of each is independent, and, while they may act in unison, they do not, and cannot, act as a unit.

The writer has not had any experience beyond the air locks; but, for several years, he has been closely associated with those who have; and he understands that all the foregoing conditions hold good. He has seen, back of the locks, rings so badly cracked and distorted that it seemed doubtful if a line of compression could be drawn which would remain within the section of the ring. It appeared evident that, while the ring had carried a great load, it was then of most service in preventing erosion of the earth and maintaining the form of its arch.

The design of retaining walls will be considered next, since it is in that respect that a pressure formula is probably most used. The results at first glance are startling. It is known, however, that many walls have failed when apparently they should not; and the writer believes that his theory shows why. It has probably been noticed that, while the theory has been developed from a revolution of the mass of earth, the pressures have been computed as arch thrust. This is not inconsistent, as at first appears, for, to exert pressure against a vertical plane, the mass of earth must develop weight enough to cause fracture and revolution of the mass, since, if it does not, the bank will stand vertically of itself and exert no pressure. In all the cases thus far taken up this revolution can easily take place; because it is im-

possible to get a perfect contact between the earth and the supporting medium; the slightest movement of the mass, however, causes crushing of the material at the bottom, and the portion above its frictional angle of repose at once becomes an arch. Mr. Haines.

In the case of a retaining wall, the filling is placed from the bottom up, and, if well compacted, and if the wall is of sufficient section, there will be no chance for the mass to revolve. The shearing strength of the material will take up most of the weight, and there will be no arch thrust against the wall. This is shown clearly in many cases by the shrinking of the material away from the wall. If, however, the wall moves, by sliding on its base, even a little; or, if water, passing through the weep-holes, carries away a small amount of the material; or, if tide water be working behind the wall and settling the mass, the arching effect of the material comes into full play, and the wall is overturned from the top.

Two conditions, then, have to be provided for: the first tending to slide the wall on its base, caused by the revolution of the mass of earth. This force, at the instant the mass moves, is equal to the entire weight of the mass revolving around a point at one-half the height, as at *A*, Fig. 43 (*a*). The center of gravity of a hemisphere is at *B*, five-eighths of the radius from *C*. The path of its revolution is from *B* to *D*. There is, then, in the pressure diagram, Fig. 43 (*b*), a force varying from zero at *A* to a maximum at *E*, as shown by the triangle, *A E F*, with its resultant applied at *D*, in Fig. 43 (*a*), normal to the wall, and tending to slide it on its base. The height, *D-E*, is five-sixteenths of the total height, and shows why, in experiments, the resultant is found at about one-third of the height.

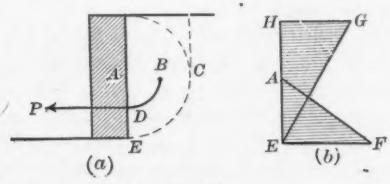


FIG. 43.

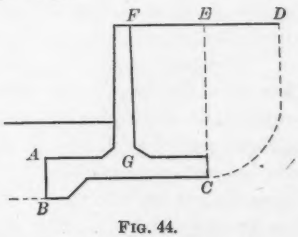


FIG. 44.

There may also be, as has been seen, an arch pressure tending to overturn the wall, as shown in Fig. 43 (*b*) by the triangle, *E G H*. There are, then, two conditions, both of which cannot occur at once, but either is likely to occur; and the wall should be able to withstand either one; but, as at present designed, it seldom is. The modern, light, reinforced wall, as usually designed, and shown by Fig. 44, does, however, fulfill these conditions to a remarkable degree, for, to slide on its base, it would not only have to overcome the friction along its base, but, also, crush the material at the toe, *A B*, or shear the earth

Mr. Haines. along a horizontal plane from *B*, and this toe is well removed from the fracture line, *C D*. To overturn the wall, also, from the arch action, it would not only have to lift the volume of earth, *C E F G*, but also shear the full height, *C E*, unless the soil fails by compression at *B*, which is possible, and should be considered in the design.

The writer believes there is but one case where it is impossible to compute the maximum pressure against a retaining wall, and that is where the material is stratified and sloping toward the wall. If the material be water-bearing, and overlying rock, or clay, it breaks away and moves toward the wall; and if the volume which would thus move, and the slope of the strata, could be determined in advance, then the maximum pressure could be determined. But these breaks often occur several hundred feet back, and the writer has known the break to occur even 1 000 ft. up the slope.

In practice, the conditions for maximum pressure do not often exist, but they should be considered. They exist sometimes, and the wall fails, this being usually attributed to faulty foundations, which is a rather poor excuse and cannot often be proved.

There is no little literature on the subject of earth pressures, but the writer has found most of it of little value, being in most cases flatly contradicted by experience. Almost without exception, it is based either on Coulomb's theory of a wedge of greatest pressure—which the writer ventures to assert does not apply to material of granular structure—or, on a hydrostatic fluid with a weight equal to earth. This, the writer contends, cannot apply, because, the material being insoluble, in order that it may act as a fluid, it becomes necessary that each particle be carried in suspension by the water; but, in order to do this, its weight must reduce to that of the water, and the hydrostatic pressure becomes that of water only.

A paper* presented before the Institution of Civil Engineers by the late Sir Benjamin Baker, Hon. M. Am. Soc. C. E., contains the results of a number of experiments, and, what is of more value, descriptions of walls which stood, and walls which failed, together with the conditions existing. The writer has found in this paper nothing directly contradictory to his theory, but much tending to confirm it.

In reference to the cracks on some 34 miles of deep-timbered trenches and tunnels, Sir Benjamin Baker stated that, on each side:

"The slope of these fissures was so uniformly at the angle of ½ to 1, measuring from the bottom of the excavation, that the resident engineer professed to be able to foretell with certainty where a building or fence wall, standing over the tunnel, would crack most."

He also stated:

"Assuming this ½ to 1 to represent Coulomb's line of least resistance, then the natural slope of repose of the material would appear to be 1⅓ to 1, which is considerably steeper than what it was in fact."

* *Minutes of Proceedings*, Inst. C. E., Vol. LXV, p. 140.

Mr. Haines.

Trautwine, also, has called attention to the fact that some walls show bulging at about one-third the height, and that all walls tend to become vertical in spite of the batter. Neither of these facts can be reasonably explained by Coulomb's wedge of greatest pressure, or by a hydrostatic theory.

A few years ago, the writer built a retaining wall which failed; but, by all the existing theories, it should have stood. This wall was a bridge abutment at a river crossing. It was about 25 ft. high, and was founded on solid rock. The base was 42% of the height, and the face had a batter of 1 in. per foot. The wall had a section in the form of a triangle, with the apex 1 ft. above the back-fill. The parapet behind the bridge seat was 20 in. thick, and the back line was brought vertically down to an intersection with the triangle. The masonry was of cut stone, in courses from 30 to 16 in. thick, laid in cement mortar, and most of it in Flemish bond. The back-fill was placed in horizontal layers, by wheel-scrapers. This abutment stood perfectly for six months, until subjected to a 10-ft. rise of the stream, when a crack appeared in the bank, at a distance back somewhat less than half the height. The wall was checked up, and found to have moved outward 4 in., but it did not then incline outward. One week later the base was in the same position, but the top inclined 8 in. outward from its original plane, and some of the courses were shoved outward.

It seemed evident to the writer that the softening of the bank by the water had caused shear and movement of the wall, followed by the arching action of the dry material above and the overturning of the wall. This abutment was torn down, and rebuilt with a base of 50% of the height. In tearing down the wall, and removing the back-fill, the crack in the bank, with the characteristic curved fracture, could be traced nearly to the bottom, and no support was given the bank either during the removal or rebuilding of the abutment. As soon as completed and the back-fill replaced, the bridge was erected, and the writer has always been puzzled to know whether that abutment was actually holding up the bridge, or the bridge holding up the abutment, and also, by what line of reasoning the responsible parties arrived at the conclusion that a wall, which had failed utterly with a base of 42% of the height, would be safe (with a reasonable factor of safety) if the base were increased to 50% of the height.

In presenting this theory, which is believed to be new, the writer would state that, while the matter has long been in his mind, its actual preparation has been made rather hurriedly.

He would also call attention to the fact that the theory makes use of but two factors, namely, the weight of the earth, which can always be obtained, and the curved line of fracture, which he has observed so many times as to lead him to believe that it follows a natural law, as he has attempted to show.

Mr. Haines. Since writing the foregoing discussion, the writer's attention has been called to an article in *Engineering News*,* by Mr. A. A. Steel, describing the apparatus used, and the results of some experiments on earth pressures.

The apparatus was of a size larger than usual, and was designed to test the pressures at different points in the height of a bank of earth. The results are interesting, and the following is abstracted from Mr. Steel's description:

"The diagram * * * gives the results of the experiments with damp earth. It will be seen that the pressure against the upper measuring board increases much more rapidly than that against the lower one. For this reason the series was discontinued shortly after the upper balances indicated a greater pressure than the lower ones. It was supposed that this was due to the earth clinging to the sides of the pit, like the sand in a molder's flask, and not settling freely. To avoid this the cohesion was destroyed by spreading the earth upon an asphalt pavement. Here, by the aid of convenient draft it was completely dried in about two weeks.

"The experiments were repeated with this dry earth, but again the pressure on the lower boards was less. This series of experiments required two days' time, and during the night the tangential component of the pressure on the upper board fell off about 60 lbs. This might have been due to a readjustment in the mass of the earth, but it seemed probable that it might have been caused by some meddlesome boy. To get a check on this and the difference in the pressure of the two boards, the series was repeated exactly, and a laborer engaged so that it could be finished in one day. The drop did not again appear * * *."

The point to which the writer would call attention is the fact that Mr. Steel had here a perfect example of the arching of loose material, for, the material being thrown in loose, the compression of the bottom material by the weight above it, and the friction of the mass settling against the boards, threw the upper portion into action as an arch, and, had the experiment been continued, some very valuable results might have been obtained.

As it is, his paper is a striking example of the extent to which one is governed by precedent, for, his apparatus being designed to accord with Coulomb's theory of a plane of rupture, his mind was unable to accept any results inconsistent with that theory, and the experiments were stopped.

Until investigators can bring themselves to make their deductions from observed facts, and not try and make the facts fit some predetermined conclusion, no really valuable results in any line can be obtained.

In conclusion, the writer thinks that the thanks of this Society are due Mr. Meem, for his paper; and, while he does not agree with

* Vol. XLII, p. 261, October 19th, 1899.

the author's theory for pressure, he believes him to be perfectly right, in the case of sheeting, in placing the base of his pressure triangle at the top, instead of at the bottom. The writer also has the greatest respect for the author's system of timbering, for, from personal observation, he can state that it performs perfectly the functions for which it is designed, while some, at least, designed in accordance with the common theories, fails utterly, and more of it shows stresses far in excess of those for which it was designed. Mr. Haines.

F. T. LLEWELLYN, M. AM. SOC. C. E.—This paper seems to be a very practical and valuable contribution to the scanty literature on this subject. Mr. Llewellyn.

It is a subject with which the speaker is not very familiar, but, during the last twelve months, having had occasion to investigate the strength of mine timbers, he has found voluminous literature telling how to frame the ends of timbers, but hardly anything suggestive of a method of calculating their stresses.

The speaker believes that in the anthracite coal regions there are some practical "rules-of-thumb" (they can hardly be called formulas) in use by the mine foremen for computing the sizes of timbering at a depth of 500 or 1 000 ft., although these rules are largely modified by personal judgment. It is interesting to note that the one most commonly used in Eastern Pennsylvania is in the line with Mr. Meem's theory, although applied to depths very much greater than those in the trenches he mentions. This rule is as follows: In order to determine the safe distance between the rooms in an anthracite coal mine, it is calculated that the distance from center to center of rooms should be 1% of the distance below the surface of the ground plus five times the thickness of the overlying seams, the whole to be divided by two.

The main point of interest is that this formula contains two elements, the first being a function of the total depth, and comparatively insignificant, while the second, being a function of the thickness of the overlying seam, is the main factor, which would seem to support Mr. Meem's theory that the pressure does not increase at any rate in direct proportion to the total depth.

It has been stated that it was unfortunate that there had been practically no large tests of lateral pressures on pilings in trenches and elsewhere, and the speaker desires to state that the company with which he is connected is now arranging to conduct a somewhat extensive series of experiments in driving steel sheet-piling, and excavating to a depth of 50 ft. At present he cannot say what arrangements will be made for the dissemination of this information, but is satisfied that the results will be presented to the engineering profession as fully as possible.

T. KENNARD THOMSON, M. AM. SOC. C. E.—The author gives a formula, for calculating the strains on the bracing for open cuts or Mr. Thomson.

Mr. Thomson. trenches, based on the angle of repose of the material, but he does not state how to find this angle, and, at the best, it could only be guessed at, for, while it would be easy to ascertain the angle for any loose material after it had been removed from the trench, it would seem to be impossible to determine it in advance of the excavation, as every foot underground is likely to disclose new conditions. Again, this assumed angle only holds good for dry material, as the author states, but there are very few cases of excavation where underground streams are not encountered; and water mains are likely to burst, and even a thunderstorm is apt to cause disastrous results.

It is quite true that it is sometimes safe to remove the bottom braces; in fact, the speaker has dug pits for elevated foundations in Brooklyn from 12 to 15 ft. deep without any bracing at all, but they were immediately filled with concrete, and, although no difficulty was experienced, it is not an example to be followed, even in Brooklyn, and certainly not in New Jersey.

In good hardpan, under air pressure, the speaker has excavated a depth of from 27 to 30 ft. without any bracing, but in many cases it would be suicidal to do this. Most New Yorkers must have seen banks of quicksand from which the water has been drained standing with a perfectly vertical face, and, when in this condition, of course, there would be no strain whatever on the bracing, and yet a slight disturbance would cause, and has caused, such banks to collapse without warning, and the daily papers have reported many cases of this kind where laborers have lost their lives.

It is quite true, as the author states, that there are many cases where his formula would not apply, so the only excuse for this discussion is the fear that some young engineer may overlook the exceptions and design his bracing by the formula, guessing at the angle of repose.

The experienced man will probably prefer to rely on his own judgment, as every case has to be studied by itself, and the more one has to do with earth or water pressures the more respect he has for their power and the less liberty he takes with them. There is probably not an experienced foundation man in the country who has not seen coffer-dam bracing collapse, sometimes at the bottom, sometimes half way up, and elsewhere.

In discussing fluid pressure, the author doubts if the full hydrostatic pressure would be found at the bottom. This is a subject which has been before the speaker for many years, in connection with deep cellars. He has put in cellar floors from 16 to 32 ft. below water, and the conclusion is that in some cases the full pressure does not occur, in many it does, while in others the pressure is much greater than the hydrostatic head would call for.

In pneumatic caissons in quicksand in New York City, where the

caissons are sunk with as little disturbance of the ground as possible, it is found necessary to keep the air pressure almost exactly at the theoretical water pressure. Many want to calculate the pressure at from 90 to 100 lb. per cu. ft., including the weight of water and sand. Mr. Thomson.

The speaker has seen a coffer-dam of 8-in. tongued and grooved sheet-piling driven several feet below the excavation before the digging started, braced with 12 by 12-in. walings, 5 ft. apart vertically at the top and less than 3 ft. apart vertically at the bottom, with 12 by 12-in. struts 6 ft. apart horizontally, and 30 ft. deep, where the waling deflected as a beam, the struts crushed 2 in. into the posts, and the timbers were pretty nearly knocked into kindling wood, the bottom caving in 2 or 3 ft.

Again, on the Canadian Pacific Railway in the Rockies, in 1885, there was a "clay" tunnel, high and dry, which was apparently all right until it was completed with heavy timber lining, when it suddenly shut up. Another effort was made, and 12 by 12-in. bracing was put in continuously instead of at intervals, and, as this tunnel also collapsed after completion, the company abandoned it and did not try again for more than 20 years, when another location was selected.

In open coffer-dam work, it is often better to use larger timbers spaced further apart than smaller sizes spaced closer, as more working room is left.

What the author refers to as sheet-piling has, in a great many cases, superseded the old-fashioned sheeting, as it is much better where it can be used, especially if the ground is wet or treacherous.

Ernst F. Jonson, Assoc. M. Am. Soc. C. E. (by letter).—This paper introduces a new problem in the theory of earth pressure, by calling attention to the fact that the accepted theory cannot be applied to all cases, especially to those in which cohesion becomes an element in the stability of a mass of earth. Mr. Jonson.

It would be well if the author's empirical formula of earth pressure on sheet-piling could be verified by some more definite data than general experience, such as measurements of the stresses in the braces. This might be done by inserting hydraulic jacks with attached gauges, at the lower ends of the braces.

The author's simile of a wedge action seems to be unfortunate. If the pressure of an embankment were of this nature, and the pressure on a unit length of sheet-piling were $P = \frac{w\ h^2\ \text{tan.}\ c}{2}$, then, according to the same reasoning, the pressure on the upper half of the sheet-piling would be $P = \frac{w\ h^2\ \text{tan.}\ c}{8}$. Hence, it is seen that the average pressure on the upper half is one-half of the average pressure on the entire height of the sheet-piling. This implies that the pres-

Mr. Jonson. sure at any one point in the height of the sheet-piling is proportional to its distance from the top of the embankment. This, again, implies that the resultant of the pressure is located at one-third of the height from the bottom, which is contrary to the author's experience.

Mr. Pruyn. FRANCIS L. PRUYN, ASSOC. M. AM. SOC. C. E. (by letter).—The writer is deeply interested in this valuable paper as he has had considerable experience with almost all the various types of subway bracing that have been used in New York City.

Mr. Meem brings a valuable thought to the consideration of the engineering profession when he emphasizes the fact that earth pressures at the bottom of a trench need not necessarily be as great as those at the top. At the commencement of his paper he states that such conditions exist in dry ground, but, in the writer's opinion, he does not bring out with sufficient clearness the fact that such pressures can obtain in dry compact material only. In this the danger lies, for the author's experience has not only been in dry ground, but, in most cases, in artificially dried ground, as is the case in any paved city. The roofs of houses and the pavements of streets, together with the sewerage systems necessary to carry off rainfall, are artificial arrangements which tend to reduce greatly the quantity of water in such excavations.

It is a well-known fact that natural springs and watercourses dry up after a city has been erected over their former sites, for the simple reason that ground-water can no longer flow toward them. This artificial condition should be carefully borne in mind when the question of using Mr. Meem's theory of earth pressure in dry ground is contemplated.

In a city every rainfall is taken care of by drainage systems, so that, unless a water main or sewer breaks, the engineer has little to fear from the increased pressure on the sheeting caused by the saturation of the ground.

In open country, no matter how dry the material may be when first excavated, saturation may take place after every rainfall, and bring about the hydraulic condition in earth pressure which the author's theory ignores.

What the writer desires to bring out is that, within certain fixed limits, Mr. Meem's theory is perfectly justifiable, but that those limits must be carefully defined and understood before any engineer attempts to design sheeting on that basis. The writer would define these conditions as those existing within cities with paved streets, and in dry material, such as sand or loam, in which the possibility of saturation by water is so remote that the contractor or engineer can afford to take the chance of the lighter bracing at the bottom of the trench.

Mr. Meem's experience, to a large extent, is based on the local conditions in the City of Brooklyn, which, of course, closely coincides with the theoretical conditions just stated.

Mr. Pruyn. The writer has had occasion to familiarize himself with the sheeting used on many parts of the present completed subway in Manhattan, as well as the Sixth Avenue subway, the Cortlandt and Fulton Street subway, and the Centre and Canal Street subways, now under construction. To show how limited is the application of Mr. Meem's theory of bracing, it is a fact that, with the exception of certain portions of the Brooklyn Loop on Centre and Canal Streets, where the conditions of a good sand and dryness of material closely approximate those of Brooklyn, it could not be used in any subway now being built in Manhattan. In all other cases the material is saturated and the hydraulic formula has to be used.

The author has done a great service to engineers and contractors in showing them how to save money in bracing and sheeting under certain peculiar conditions. For this the profession owes Mr. Meem a great debt of thanks. The writer's only point of criticism is that the limits of the application of his formula should be defined more distinctly, and should always be kept clearly in mind by the engineer who attempts to use it.

Mr. Shailer. R. A. SHAILER, M. AM. SOC. C. E.—The speaker is exceedingly interested in this paper, but, during all the latter part of his life, he has been so much on the practical side of engineering that he must confess he is inclined to be cautious in reference to formulas and theories regarding earth pressures. Mr. Meem's theory is based on perfectly tight sheathing, which practically eliminates the trouble all have in getting competent workmen. With the men available, the timbering, in all cases, must be strong enough to hold the ground in case the sheathing is not tight. The theoretical discussion of such matters is interesting, and, undoubtedly, real good will come from it, but, to the younger engineers the speaker would say:

"Do not take chances, but be safe. You must not put in a 6 by 6-in. stick because 'theory' says it will hold, but double the size, and perhaps double it again, unless you are dead sure of every condition surrounding the work."

There is one point about the movement of earth in excavation which has been brought home to the speaker by experience, that is the advisability of getting the masonry in as soon as possible wherever the excavated material has a tendency to move. Swelling clay will stand oftentimes from two to three days without any perceptible movement. If timbered and left for a week or two, quite probably the timbers will be found cracked and buckled, be they ever so heavy; therefore, in clay tunnels, constant and steady progress of completed work is almost a necessity.

The importance of driving the braces tight in an excavated trench to prevent as far as possible the movement of earth or sand back of the sheathing, has already been brought out. In the speaker's opinion, this is a matter that deserves the closest attention, for, from the moment the movement of the material commences, the trouble begins.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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WATER PURIFICATION AT ST. LOUIS, MO.

Discussion.*

BY MESSRS. PHILIP BURGESS AND EDWARD PRINCE.

Mr. Burgess.

PHILIP BURGESS, ASSOC. M. AM. SOC. C. E. (by letter).—The writer has been engaged for the last year and a half in making tests of the various water purification plants in Ohio, for the State Board of Health, and has read with much interest Mr. Wall's paper on the design and operation of the St. Louis plant. There are, however, two or three points in the operation of this plant which differ from the method ordinarily used at filter plants, and are not discussed in the paper. Among these is the practice of using such large amounts of lime, with a consequent reduction in the hardness of the treated water.

It is stated in the paper that the amount of lime used is as much as the water will stand, and that lime is added until the water in the last basin is slightly caustic. This means that, while the river water contains generally two or three parts of carbon dioxide per million, and hence no normal carbonates, all the free and half-bound carbon dioxide is eliminated by the treatment, producing a water that contains only normal carbonates and, at times, even a slight caustic alkalinity. The question arises: is the use of a large amount of lime necessary for proper coagulation? The chemical reactions, as stated in the paper, show a reduction of the bicarbonates by the treatment, and the use of lime in amounts beyond that necessary for the removal of the acid iron salts formed by addition of the copperas solution to the raw water.

* This discussion (of the paper by Edward E. Wall, M. Am. Soc. C. E., printed in *Proceedings* for September, 1907), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Mr. Burgess.

The following statement gives the results of the reactions of the coagulants in those filter plants in Ohio where copperas and lime are used as coagulants. There is first a reaction of the copperas on the raw water, before lime is added, causing a reduction of the bi-carbonate alkalinity and the formation of acid iron salts. Lime is then added to neutralize the iron salts, and the total alkalinity is brought back to about the original content of the raw water. A further increase in the amount of lime added gives an increase in the amount of total alkalinity, a condition which obtains until a point is reached at which a softening action by the lime begins. Beyond this point the further addition of lime results in the decrease of the total alkalinity, a reduction varying with the amount of lime used, and similar to that at all water-softening plants. The amount of normal carbonate present before there is any softening action has, in the winter, been found to be as high as 32 parts per million even 6 hours after the coagulants had been added.

In many filter plants where lime and copperas are used as coagulants, it is the custom to add first the copperas and then the lime until a sufficient quantity of the latter is present to give a treated water which is slightly alkaline to phenolphthalein. In general, it may be said that the use of 1.0 gr. of copperas per gallon requires 0.4 gr. of lime per gallon (in bulk) to give a water containing a small amount of normal carbonates. Whether or not there is a final reduction of the total alkalinity of the treated water, seems to depend on the character of the raw water, its temperature, and somewhat on the time which elapses between the introduction of the coagulants.

At Marietta, Ohio, there is a filter plant using lime and iron for coagulants, where very careful records of the operation of the filter plant are kept; the results there are characteristic of those at similar plants where lime and iron are used. Table 7 shows the monthly averages of the daily determinations made during the last 6 months by Mr. George M. Gadsby, who has been retained as chemist at the plant.

The most striking feature of Table 7 is the great variations in the bacterial efficiencies obtained by the basins, namely, from 50 to 94.4 per cent. The operation of the plant was somewhat hindered during March by the very high stage of water in the Ohio River, which resulted in a decrease in the efficiency of the coagulating basins, but the chief cause of the poor results obtained during March and April was that not quite sufficient lime was used. The necessity of having the water slightly alkaline to phenolphthalein was not appreciated, and the effluent from the filters was frequently slightly acid to phenolphthalein. It should be noted, however, that practically no iron went through the filters, even under this condition. Beginning on May 1st, more attention was paid to having a small amount of normal

TABLE 7.—ANALYSES OF RAW WATER AND EFFLUENT FROM FILTERS, MARIETTA, OHIO.
(Parts per Million.)

	MARCH.		APRIL.		MAY.		JUNE.		JULY.		AUGUST.		AVERAGE.	
	Raw.	Eff.	Raw.	Eff.	Raw.	Eff.	Raw.	Eff.	Raw.	Eff.	Raw.	Eff.	Raw.	Eff.
Turbidity	300	0	175	0	220	0	170	0	1 500	0	250	0	435	0
Color	6	8	6	6	10	6	13	15	18	15	10	8	10.5	9.7
Total alkalinity	17	21	18	20	22	27	25	30	30	33	28	31	23	27
Phenol alkalinity	0	0	0	0	0	+2	0	+3	0	+2.5	0	+3*	0	+1
Incrustants	33	42	35	46	21	34	19	32	20	42	43	55	28	42
Total hardness	50	63	53	66	43	61	44	62	50	75	71	86	52	69
Calcium	.....	.....	18	23	15	20	15	24	21	31	27	34	19	26
Iron	.....	.....	0.05	0.08	0.11	0.06	0.11	0.11	0.10	0.09	0.06	0.05	0.09	0.08
Copperas, in grains per gallon.	3.38		1.17		2.06		2.14		3.25		1.65		2.27	
Lime, in grains per gallon	0.95		0.82		0.83		0.85		1.23		0.67		0.89	
Bacterial efficiency of coagulating basins	50.0%		67.4%		87.8%		80.6%		94.4%		84.8%		77.5%	

* Estimated.
Raw water contains from 2 to 4 parts per million of free carbon dioxide. Length of period of sedimentation = 3.5 hours.

carbonates in the treated water, with the result that the efficiency of the basins increased immediately to nearly 90 per cent. In other words, the use of a very few more pounds of lime increased the efficiency 20 per cent. Mr. Burgess.

The tendency to use the least possible amount of lime was not due to inadvertence, but to the fact that previously, when lime was used in such quantities as to give 20 to 40 parts of normal carbonates per million in the treated water, the air pipes in the filters were clogged by lime incrustants and had to be removed and cleaned. It was with the intention of avoiding a recurrence of this condition that the least possible amount of lime was used.

At Lorain, Ohio, lime and copperas have been used as coagulants in the old purification plant since 1903. Lime is generally used in such quantities as will give a small amount of normal carbonate in the effluent, but the occasional use of too large amounts of lime, where the coagulation period is only 20 min., has caused the formation of after-deposits of lime on the grains of the sand, resulting in an increase in the effective size from 0.52 to 0.61 mm. By analysis, the sand in the filters was found to be covered with lime to the extent of 37% of its weight. It is manifestly impossible to obtain satisfactory results from the filters under such conditions. It has been stated that a rapid application of wash-water tends to remove these after-deposits of lime, but the writer has no definite information on this point.

From the foregoing facts, it is apparent that the proper use of lime and copperas, as coagulants for filtration, requires a constant and accurate adjustment between these two materials, such that the treated water shall contain a small, and only a small, amount of normal carbonates. Under such conditions, there is caused an increase in the total hardness of the water, amounting to about ½ gr. per gal. for each grain of copperas added, accompanied by slight change in the temporary hardness and a removal of about 33% of the color. It will appear, also, that in the lime and copperas treatment, as applied at St. Louis, not only is the coagulation obtained from the copperas, but the treatment is one of softening the water. The coagulating masses formed by the softening treatment are large, flocculent, and very efficient in the removal of suspended matters and bacteria; and to this is probably due much of the success of the plant at St. Louis. Also, the large removal of color at St. Louis is undoubtedly due to the softening treatment, without which probably only one-third of the dissolved color would be eliminated.

The use of such large quantities of lime, where sedimentation and clarification alone are relied on for the purification of the supply, is shown to be necessary at such plants as that at St. Louis; but, from the foregoing discussion, it would seem to be shown that this practice is not advisable in connection with the coagulation of water applied to filter plants, on account of the clogging of the sand and pipes by after-deposits.

Mr. Prince.

EDWARD PRINCE, M. AM. SOC. C. E. (by letter).—No one can read this interesting and instructive paper without a feeling of satisfaction at the recital of efforts ending in success so well earned.

In 1846 the writer first knew St. Louis water, when, on his way to college, he visited his brother, David Prince, M.D., Professor in Pope's College, whose office was at the corner of Fourth and Olive Streets (then the heart of the city). It was the habit of Dr. Prince to draw two buckets of muddy water from his faucet, at about 6 P. M., and set them away to settle over night, say 12 hours. The next day he would use the rather milky-looking water for drinking and lavation. This was the general custom, and few used a strainer of any kind, although thousands of acres of excellent tripoli existed in untold quantities in Missouri. Some few people—laundrymen, and others—used a little alum to clear the water over night, for rinsing clothes on the following day. About $\frac{3}{8}$ in. of jelly-like mud was deposited at the bottom of the clear-water buckets after 12 hours' subsidence. The popular opinion then was that the Missouri mud was very healthful, and promoted good digestion.

The St. Louis water also possessed another excellent quality, as proven by the fact that the United States Navy sent to St. Louis for quantities of Missouri River water for use on long cruises, and particularly for use on the voyages in the South Atlantic, because this water never soured nor turned to bilge-water aboard ship, as most waters would.

When the writer was building the water-works at Quincy, Ill., in 1873, and operating them in subsequent years, he became very well acquainted with the late Thomas J. Whitman, M. Am. Soc. C. E., then Chief Engineer of the St. Louis Water-works, and at one time an honored Vice-President of this Society.

Several times Mr. Whitman showed the writer the subsiding reservoirs in operation. At that time there were four of these basins, each of 16 000 000 gal. capacity, or about a day's supply in all.

The quantity of silt deposited seemed to be enormous, and, of course, this deposit had to be removed. These subsiding reservoirs, as remembered by the writer, were constructed of cut stone, with vertical sides on the water faces, and as shown in Plate LXXXII, and in each, at 1, 2, 3, and 4, as shown by a double line, there was a sluice, about 5 ft. wide and 1 ft. deep, having a gentle slope and communicating with a sewer running to the river. The outside of the bottom of each reservoir was a little higher than the sluice at any point, and the slope was probably about 1 in 100.

To get rid of the deposit was a serious problem. Mr. Whitman tried all probable ways, such as the use of hose nozzles, solid and spray, large and small, with powerful pumps, but in vain. The jets simply honeycombed the, say, 10 or 12 in. of thick, caked, jelly-like mud.

Mr. Prince.

He finally adopted the following simple method: The reservoir to be cleaned was drained, and, commencing at the upper end, a sufficient number of men were provided with stout-handled push-boards, say 10 or 12 in. wide, and 2 or 3 ft. long, probably with one light steel edge for cutting, and it was really surprising to see these men move to the sluice so easily such large cakes of silt. Then, the water let in at the sides, for the purpose of lubrication only, completed the transportation to the river. Considering the condition of the silt, after several weeks of settlement and compacting, this, no doubt, was the best way to clean out the reservoir and get rid of the deposit at the least cost.

It is interesting and remarkable that, at the intake, Chain of Rocks, St. Louis gets its water mostly from the Missouri River, although the two rivers unite several miles above this point. After the Missouri River (often called The Big Muddy) empties into the Mississippi, the waters do not commingle, and, usually, the line of demarcation can be seen, by the difference in the color (turbidity) of the two rivers, for miles below the city. This and many of the foregoing remarks have been made simply to emphasize the fact that it was a great problem at St. Louis to obtain clear water economically, and in great quantity, from water holding so much solid matter in suspension.

Some credit, also, is due to Mr. Charles R. Henderson, former Superintendent of the Quincy Water-works, for first having found out the proper proportions of chemicals to use in the process of water coagulation and subsidence resulting in clear water. He is now connected with the water-works at Waterloo, Iowa, and has exerted himself very cheerfully to impart all the information gleaned from very long continued and carefully made experiments.

The methods and appliances in use and to be brought into use in St. Louis for the purification of the water are the results of persistent study and experiment. They are quite an advance on the Quincy methods, in many respects, and seem to be very complete.

It is possible, however, that some cheaper coagulant may be discovered, which will dispense with the use of sulphate of iron; and yet, at the present time, sulphate of iron as a coagulant and lime (water or milk) as a precipitant have no successful rivals for water-works purposes.

It is likely that the addition of subsiding reservoirs Nos. 7 and 8 will be found to be worth very much more than they will cost, for obvious reasons. With the evidently rapid growth of St. Louis, it is likely that still more subsiding reservoirs, and possibly the enlargement of the intake at Chain of Rocks, will become necessary and desirable.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

ALBERT JOHNSTONE CAMPBELL, Assoc. M. Am. Soc. C. E.*

DIED MARCH 23D, 1907.

Albert Johnstone Campbell was born at Stoke, England, on December 7th, 1854, and was the last survivor of the ancient family of Glen Saddel. As lineal heir of the Earls of Crawford and Lindsay, he was claimant to the dormant Earldoms of Annandale and Hartfield.

After being educated at Rugby, he entered the Royal School of Mines, passing successively through the Chemical, Metallurgical, Geological and Physical Sections, and being awarded the Associateship of Mines in 1876. The next four years were spent in the study of practical mining and engineering in Cornwall and Spain, and in 1880 he was appointed General Manager of the Trojes and Anjangeo Silver Mines and Smelting Company, in the State of Michoacan, Mexico, which position he held for three years, carrying out the successful development of the mines, and introducing many improvements in the system of smelting and general organization of the works.

In 1883, Mr. Campbell joined Mr. H. V. Rudston Read in a partnership, as Consulting and Constructive Engineers, with a branch establishment in Mexico, and, while in that country, carried out many important engineering works, for the Mexican Government and by private contracts, amounting to many millions of dollars. The principal work, and the one with which Mr. Campbell's name will always be associated, was the construction of the Tequixquiac Tunnel for the drainage of the Valley of Mexico, the length of the tunnel being 6¼ miles—at that time the longest tunnel in existence.

The splendid organization and ability displayed by Mr. Campbell in carrying through this work in the face of the greatest difficulties was recognized officially by the President and Government of Mexico, and, at a later date, the Committee of the Chicago Exhibition presented Mr. Campbell's firm with a gold medal as some recognition of the magnitude and importance of the work, and of the skillful engineering displayed in its performance. Also, in conjunction with his partner, he built the Mexican Southern Railway, which was the first railway in Mexico to cross the Sierra Madre Mountains, and, up to that date (1892), was the only railway in Mexico which had been completed from the start with permanent work in every detail. The time allowed for the construction of this road was ten years, but it was

* Memoir prepared by F. W. Abbot, M. Am. Soc. C. E.

completed in three years, and a bonus of $1 800 000 was earned on that account. The railroad was fully ballasted, with all masonry, culverts, bridges, etc., in position. One-third of this line is probably one of the heaviest pieces of railroad work on the North American Continent, 60 miles of it being constructed in a cañon with 4% grades. In its construction it was necessary to build 150 miles of side-roads to carry in supplies to the 8 000 men employed on the work.

The characteristic zeal and energy with which Mr. Campbell threw himself into these and other works in which he was engaged while in Mexico led to the serious undermining of his health; in fact, the illness which necessitated the operation from which he subsequently died, was directly traceable to the fevers contracted twenty years before in the Mexican swamps.

Mr. Campbell was elected an Associate Member of the American Society of Civil Engineers on May 2d, 1894. He was also a Member of the Institution of Mechanical Engineers, a Member of the Institution of Civil Engineers, and an Associate of the Royal School of Mines.

JOSEPH WILLIAM ZIPPERLEIN, Assoc. Am. Soc. C. E.*

DIED JULY 22D, 1907.

Joseph William Zipperlein, born in Philadelphia, Pennsylvania, on February 13th, 1870, was the youngest son of Charles and Louisa Zipperlein. He attended the public schools of Philadelphia until 17 years old, when he left school to accept a position in the publishing house of Lea Brothers. After about one year's service he resigned, to begin, in November, 1888, his career in the cement business, entering the employ of the Commercial Wood and Cement Company as stenographer, from which position he gradually advanced to that of Secretary in 1891. At this time he withdrew from the company in order to become identified with The William G. Hartranft Cement Company, as Vice-President, a position which he held continuously until his death.

Mr. Zipperlein was closely identified with the development of the American Portland cement industry, being a pioneer salesman, not only in the United States, but also in Canada; and, in the latter country, he has been financially interested in the cement industry since 1898.

Mr. Zipperlein was beloved by all who knew him. He was of modest disposition, amiable, tactful, a staunch friend, and a thoroughly honorable business man. Quiet and even tempered, honest in all his

* Memoir prepared by Richard L. Humphrey, M. Am. Soc. C. E.

dealings, resourceful in his work, he commanded, not only the entire confidence and respect of his business associates, but of his employees as well.

In the summer of 1906 sickness forced him to go abroad, and, although the trip proved beneficial, he never fully regained his health, but suffered almost continuously until his death, on July 22d, 1907.

He was elected an Associate of the American Society of Civil Engineers on June 4th, 1901. A large number of friends and acquaintances mourn his untimely death.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

(INSTITUTED 1852.)

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DECEMBER, 1907.

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NEW YORK 1907.

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ON ENGINEERING EDUCATION:—Desmond FitzGerald, Benjamin M. Harrod, Onward Bates, D. W. Mead, Charles Hansel.

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER.....5913 Columbus.
CABLE ADDRESS....."Ceas, New York."

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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MINUTES OF MEETINGS.

OF THE SOCIETY.

November 20th, 1907.—The meeting was called to order at 8.30 P. M.; Director A. L. Bowman in the chair; Chas. Warren Hunt, Secretary; and present, also, 200 members, and 66 guests.

A paper by William H. Burr, M. Am. Soc. C. E., entitled "The Reinforced Concrete Work of the McGraw Building," was presented by the author. Written communications on the subject from Messrs. H. F. Tucker, W. J. Douglas, Carl Gayler, J. A. Jamieson, T. L. Condron and F. F. Sinks, were presented by the Secretary. The paper was discussed orally by Messrs. E. P. Goodrich, Walter M. Smith, Guy B. Waite, E. W. Stern, and the author.

The Secretary announced the death of PAUL ERNEST OBERNDORF, elected Junior, February 5th, 1907; died November 9th, 1907.

Adjourned.

December 4th, 1907.—The meeting was called to order at 8.30 P. M.; Director A. L. Bowman in the chair; Chas. Warrent Hunt, Secretary; and present, also, 79 members, and 19 guests.

The minutes of the meetings of October 16th and November 6th, 1907, were adopted as printed in the November number of *Proceedings*.

A paper by Owen B. French, M. Am. Soc. C. E., entitled "Invar (Nickel-Steel) Tapes on the Measurement of Six Primary Base Lines," was presented by John F. Hayford, M. Am. Soc. C. E. Written communications on the subject from Messrs. J. A. Ockerson and Horace Andrews were presented by the Secretary, and the paper was discussed orally by Messrs. H. J. Howe, Charles Macdonald, Noah Cummings, C. E. Trout, and J. F. Hayford.

Ballots for membership were canvassed, and the following candidates elected:

As Members.

Alexander Leslie Black, New Orleans, La.
Francis Blossom, New York City.
William Charles Boyd, Pittsburg, Pa.
George Robert Graham Conway, Monterey, Mexico.
Samuel Forder Crecelius, Louisville, Ky.
Loring Nelson Farnum, New York City.
James Bowman Goodwin, McCall Ferry, Pa.
Ralph Hadlock Ober, Vulcan, Wash.
Umesaburo Ogawa, Kyoto, Japan.
Edward Jones Pearson, Seattle, Wash.
Julius Pitzman, St. Louis, Mo.
Henry Souther, Hartford, Conn.
Charles Coker Wilson, Columbia, S. C.

As Associate Members.

Mandayam Ananthampillai Ananthalwar,
Channapatna, Mysore, India.
Charles Noble Bennett, Charleroi, Pa.
Joseph Alexander Donahey, Darrowville, Ohio.
Theodore Christian Fischer, Elizabeth, N. J.
John Clyde Fruit, Chicago, Ill.
Harry Todd Griswold, New York City.
August Frederick Hartman, New York City.
Henry Perez Hoyt, Millinocket, Me.
Charles Wilson Killam, Boston, Mass.
Earle Kelly Knight, Camagüey, Cuba.
Maurice Joseph Leahy, Hamilton, Ohio.

Robert James Middleton, Ottumwa, Iowa.
Ray Murray, Poughkeepsie, N. Y.
Charles Henry Quimby, Jr., Mt. Vernon, N. Y.
Julian Pierre William Richmond, New York City.
Ralph Hamilton Stearns, New York City.
George Sykes, New York City.
Howard Edward Van Ness, Little Falls, N. J.
Samuel Judson Van Ornum, Pasadena, Cal.
Edward Beaumont Wardle, New York City.
Henry Wright Woodcock, Brooklyn, N. Y.
Albert Menger Zabriskie, Plainfield, N. J.

The Secretary announced:

The transfer of the following candidates by the Board of Direction on December 3d, 1907:

From Associate Member to Member.

William Hoyt Balch, Boston, Mass.
Thomas Jenks Carlile, Jamaica, N. Y.
Robert Hawxhurst, Jr., Antofagasta, Chili.
Leon Solomon Moisseiff, New York City.
Williford Harry Terrell, Clyde, N. C.
Henry Arthur Van Alstyne, New York City.

The election of the following candidates by the Board of Direction:

As Juniors.

On October 1st, 1907:

Nathan Benedict, Bocas del Toro, Panama.

On November 5th, 1907:

William Alfred Lamb, Sacramento, Cal.
Fulton Pace, Caldwell, Idaho.

On December 3d, 1907:

Charles Frederick Breitzke, New York City.
Herbert Edward Cantwell, Albany, N. Y.
Henry Helm Clayton, Amarillo, Tex.
Edgerton Chester Garvin, Washington, D. C.
Irving Dean Goodwin, Ann Arbor, Mich.
Wilfred Lewis, Dubuque, Iowa.
Henry Warner Maynard, Seattle, Wash.

The Secretary announced the following deaths:

ABRAHAM BEEKMAN COX, elected Member, April 1st, 1874; died February, 1906.

EDWARD ADINO HANDY, elected Member. January 2d, 1889; died November 21st, 1907.

GEORGE THOMAS NELLES, elected Member, October 3d, 1888; died November 15th, 1907.

B. C. RUMSEY, elected Fellow, May 12th, 1870; date of death unknown.

Adjourned.

December 18th, 1907.—The paper by J. T. Fetherston, Assoc. M. Am. Soc. C. E., entitled "Municipal Refuse Disposal: An Investigation," is to be presented. Because of the necessity for going to press with this number of *Proceedings* in advance of this meeting, the publication of the minutes will be deferred until January, 1908.

OF THE BOARD OF DIRECTION.

(Abstract.)

November 5th, 1907.—Past-President Noble in the chair; T. J. McMinn, acting as Secretary; and present, also, Messrs. Bissell, Bowman, Gibbs, Hazen, Knap, and Smith.

Applications were considered and other routine business transacted.

Five Associate Members were transferred to the grade of Member, and sixteen candidates for Junior were elected.

Adjourned.

December 3d, 1907.—Vice-President Bensel in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs, Bowman, Christie, Landreth, Noble, Schneider, Sherrerd, Smith, Stearns, Swensson, and Tillson.

Denver, Colorado, was selected as the place for holding the Fortieth Annual Convention of the Society, and the time for holding that Convention was fixed as June 30th to July 3d, inclusive.

The date for holding the first Society meeting in 1908 was changed from January 1st to January 8th.

Messrs. C. M. Ingersoll, Jr., James H. Brace, and Chas. Warren Hunt were appointed a Committee to take charge of the arrangements of the Annual Meeting.

The following resignations were accepted:

John A. Cosmus, H. P. Macdonald, J. A. McCrea, Edward B. Thornhill, Charles G. Waitt, S. T. Wellman.

Applications were considered and other routine business transacted.

Six Associate Members were transferred to the grade of Member, and ten candidates for Junior were elected.

Adjourned.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, January 8th, 1908.—8.30 P. M.—Ballots for membership will be canvassed, and there will be an informal discussion on The Use of Reinforced Concrete in Engineering Structures. E. P. Goodrich, M. Am. Soc. C. E., will introduce the discussion, and it is hoped that it will be continued by a number of others. All are invited to speak or to send written communications on the subject.

Wednesday and Thursday, January 15th and 16th, 1908.—The Fifty-fifth Annual Meeting will be held. The Business Meeting will be called to order at 10 o'clock on Wednesday morning at the Society House. The Annual Reports will be presented, officers for the ensuing year elected, members of the Nominating Committee appointed, a proposed amendment to the Constitution presented for action, the Report of the Special Committee on Rail Sections, printed in *Proceedings* for August, 1907, page 290, will be presented for discussion, and other business transacted.

Arrangements for the Annual Meeting have been placed in the hands of a committee composed of Messrs. C. M. Ingersoll, Jr., James H. Brace, and Charles Warren Hunt, and a general programme will soon be issued.

Wednesday, February 5th, 1908.—8.30 P. M.—Ballots for membership will be canvassed, and two papers will be presented for discussion, as follows: "Overhead Construction for High-Tension Electric Traction or Transmission," by R. D. Coombs, Assoc. M. Am. Soc. C. E.; and "A New Suspension for the Contact Wires of Electric Railways Using Sliding Bows," by Joseph Mayer, M. Am. Soc. C. E.

These papers are printed in this number of *Proceedings*.

ANNUAL CONVENTION.

The Board of Direction at its meeting, December 3d, 1907, decided that the Fortieth Annual Convention shall be held in Denver, Colo., beginning on Tuesday, June 30th, and ending Friday, July 3d, 1908.

The Secretary thinks it is wise in announcing the above fact to state that since that time it has been decided to hold the Democratic National Convention in Denver beginning July 7th, 1908, and it seems probable that a change in the date of our Convention will be necessary on that account. This will have to be decided by the Board of Direction at its next meeting, and the result will be announced later.

NOMINATING COMMITTEE.

The Constitution provides that at the Annual Meeting of each year, seven Corporate Members, not officers of the Society, one from each of the Geographical Districts into which the Society is divided for this purpose, shall be appointed by the meeting to serve for two years. In consequence of the death of Charles Davis, M. Am. Soc. C. E., it will be necessary to appoint two members for District No. 4.

The usual blank request for suggestions as to representatives of each district, for presentation to the meeting, has been mailed to Corporate Members.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms and at all meetings:

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Society of Engineers, 17 Victoria Street, Westminster, S. W., England.

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Civil Engineers' Club of Cleveland, 718 Caxton Building, Cleveland, Ohio.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa.

Engineers' Society of Western Pennsylvania, 803 Fulton Building, Pittsburg, Pa.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

Louisiana Engineering Society, 604 Tulane-Newcomb Building, New Orleans, La.

Engineers' Club of Central Pennsylvania, Corner Second and Walnut Streets, Harrisburg, Pa.

Engineers' and Architects' Club of Louisville, Ky., 303 Norton Building, Fourth and Jefferson Streets, Louisville, Ky.

Teknisk Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Société des Ingénieurs Civils de France, 19 Rue Blanche, Paris, France.

Svenska Teknologförenigen, Brunkebergstorg 18, Stockholm, Sweden.

Institute of Marine Engineers, 58 Romford Road, Stratford, London, E., England.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Pacific Northwest Society of Engineers, 617–618 Pioneer Building, Seattle, Wash.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Memphis Engineering Society, Memphis, Tenn.

Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

The Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Institution of Engineers of the River Plate, Buenos Aires, Argentine Republic.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Cleveland Institute of Engineers, Middlesbrough, England.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Rochester Engineering Society, Rochester, N. Y.

Brooklyn Engineers' Club, 197 Montague Street, Brooklyn, N. Y.

Montana Society of Engineers, Butte, Montana.

SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling, compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only, are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

In reference to this work, the Appendix* to the Annual Report of the Board of Direction for the year ending December 31st, 1906, contains a summary of all searches made to that date.

Proceedings, Vol. XXXIII, p. 20 (January, 1907).

ACCESSIONS TO THE LIBRARY.

(From November 12th to December 9th, 1907.)

DONATIONS.*

PLANE SURVEYING.

A Text-book and Pocket Manual. By John Clayton Tracy. Morocco, 7 x 4 in., illus., 27 + 794 pp. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1907. $3.00.

It is stated in the preface to this book that no attempt has been made to cover the whole field of surveying, the aim of the author being only to meet the requirements of the new methods of teaching surveying, especially in connection with summer courses, and to discuss thoroughly the fundamental principles and methods of plane surveying. The subject-matter is divided into three parts: I, Field Work; II, Office Work; and III, The Care and Adjustment of Instruments. The use of instruments, the general methods of procedure and the practical details of field work are explained and discussed in Part I. In Part II are shown various methods for checking, the systematic treatment of note-keeping, with illustrative examples of field work, and methods of compilation and plotting, together with chapters on finishing maps and on lettering. A critical study of the construction and adjustment of instruments, with a special chapter on their care, is made in Part III. Eighteen tables containing solutions of various problems in surveying are included, some of which are reprints. There is also an index of thirty pages.

MECANIQUE ELECTRICITE ET CONSTRUCTION

Appliquées aux Appareils de Levage: Les Ponts Roulants Actuels. Par Louis Rousselet. Paper, 11 x 7½ in., illus., 6 + 554 pp. Paris, H. Dunod et E. Pinat, 1908. 35 francs.

The Contents are: Part I, Generalities; Moteurs. Part II, Treuils; Freins; Vis sans Fin; Suspensions. Part III, Moufles et Palans. Part IV, Operateurs. Part V, Direction et Translation. Part VI, Projet des Mécanismes d'un Chariot de Pont Roulant. Part VII, Charpentes de Pont a Ames Pleines pour Poutres Principales. Part VIII, Les Ponts Roulants Actuels: Choix; Description d'Appareils Construits; Poids; Prix de Revient et de Vente. Appendice.

EXPLOITATION DU PETROLE:

Historique, Extraction, Procédés de Sondage, Geographie et Géologie. Recherches des Gites, Exploitation des Gisements Chimie, Théories de la Formation du Pétrole. Par L.-C. Tassart. Paper, 11 x 7½ in., illus., 14 + 726 pp. Paris, H. Dunod et E. Pinat, 1908. 35 francs.

In this, the first volume of this publication, the author discusses the petroleum industry only from the geological point of view. A description of the methods used in various countries in boring for the crude material is followed by a discussion of the geographical and geological distribution of petroleum, the chemical properties of crude petroleum and the principal substances which enter into its composition, and the various theories advanced as to its origin.

LES OSCILLATIONS DU MATERIEL DES CHEMINS DE FER ET LA VOIE.

Stabilité des Automobiles. Par Georges Marie. Paper, various sizes, illus., 5 vol. Paris, H. Dunod et E. Pinat, 1906-07. Vol. 1, 4 francs; Vol. 2, 2 francs; Vol. 3, 2 francs; Vol. 4, 4 francs; Vol. 5, 2 francs.

The first four volumes of this publication, crowned by the Academy of Science in December, 1906, are stated to represent a scientfic study of the oscillations of railway materials and track and the possible derailments resulting therefrom. In

* Unless otherwise specified, books in this list have been donated by the publisher.

the fifth volume the author shows how the theories and formulas given in the previous volumes may be applied to a study of the stability of automobiles. The Contents are: Vol. I, Les Dénivellations de la Voie et les Oscillations du Matériel de Chemins de Fer; Vol. II, Les Oscillations du Matériel des Chemins de Fer à l'Entrée en Courbe et à la Sortie; Vol. III, Les Grandes Vitesses des Chemins de Fer, les Oscillations du Matériel et la Voie; Vol. IV, Les Oscillations du Matériel Dues au Matériel Lui-Même; Vol. V, Formule Relative à une Condition de Stabilité des Automobiles et Spécialement des Autobus.

Gifts have also been received from the following:

Abel & Imray. 1 pam.
Am. Inst. of Elec. Engrs. 1 bound vol.
Am. Inst. of Min. Engrs. 1 pam.
Am. Ry. Eng. & M. of W. Assoc. 1 vol.
Am. Water Works Assoc. 1 bound vol., 1 vol.
Boston, Mass.-Board of Commrs. of the Dept. of Parks. 1 pam.
Boston, Mass.-Public Library. 1 pam.
Brit. Fire Prevention Comm. 1 bound vol.
Cape of Good Hope-Govt. Stationery Office. 1 pam.
Chicago, Ill.-Bureau of Statistics and Municipal Library. 1 pam.
Chicago & Alton R. R. Co. 1 pam.
Colo. Agri. Coll.-Agri. Exper. Station. 3 pam.
Coorg, India-Public Works Dept. 1 pam.
Cornell Univ. Library. 1 pam.
David Lupton's Sons Co. 1 bound vol.
Eastern Bengal and Assam-Secretariat Book Depôt. 1 pam.
Eng. Standards Comm. 1 pam.
Engrs.' Soc., Univ. of Minnesota. 2 pam.
Farley, G. P. 130 bound vol.
Fisk & Robinson. 1 pam.
Great Northern Ry. Co. 1 pam.
Hering, Rudolph. 1 pam.
Herschel, Clemens. 1 pam.
Illinois Univ.-Agri. Exper. Station. 3 pam.
Indiana-R. R. Comm. 1 map.
Johnson, G. A. 1 pam.
Luiggi, Luigi. 1 pam.
Manchester Assoc. of Engrs. 2 bound vol.
Mass.-Board of Health. 1 bound vol.
Master Car Builders' Assoc. 1 bound vol.
Mexican Ry. Co., Limited. 4 pam.
Mich.-State Board of Health. 1 bound vol.
Miss. River Comm. 1 pam.
Montreal, Que.-City Council. 1 bound vol.
New Jersey-Board of Health. 1 vol.
New Jersey-Geol. Survey. 2 bound vol.
New South Wales-Bureau of Statistics. 2 pam.
New York City-Dept. of Water Supply, Gas and Electricity. 1 pam.
New York-State Dept. of Health. 7 bound vol.
New York City Record. 4 bound vol.
Owen, James. 1 bound vol.
Ry. Signal Assoc. 1 pam.
Royal Military Coll. Club of Canada. 1 vol.
Royal Soc. of New South Wales. 1 vol.
St. Louis, Mo.-Public Library. 1 pam.
Smithsonian Institution. 1 bound vol., 1 vol.
South Australia-Ry. Commr. 1 pam.
South Carolina-R. R. Commrs. 1 map.
Sydney Univ. Eng. Soc. 1 vol.
Underwriters' Laboratories, Inc. 1 pam.
U. S. Bureau of Plant Industry. 1 pam.
U. S. Bureau of Statistics. 1 pam.
U. S. Bureau of the Census. 1 bound vol., 3 pam.
U. S. Bureau of Yards and Docks. 1 vol.
U. S. Corps of Engrs. 13 specif.
U. S. Interstate Commerce Comm. 14 pam.
U. S. Isthmian Canal Comm. 1 vol.
U. S. Lake Survey Office. 1 pam.
U. S. Library and Naval War Records Office. 5 pam.
Worcester, Mass.-Mayor. 15 vol.

BY PURCHASE.

Repertorium der Technischen Journal-Literatur. Herausgegeben im Kaiserlichen Patentamt, Jahrgang, 1906. Berlin, Carl Heymanns, 1907.

Resistance des Materiaux Appliquee aux Constructions, Vol. III. Par Ernest Aragon. Paris, H. Dunod et E. Pinat, 1908.

Peat: Its Use and Manufacture. By Philip R. Björling and Frederick T. Gissing. London, Charles Griffin & Company, Limited, 1907.

Kurzes Lehrbuch der Elektrotechnik. Dritte, verbesserte Auflage. Von Dr. Adolf Thomälen. Berlin, Julius Springer, 1907.

Beton-Kalender, 1908; Taschenbuch für Beton- u. Eisenbetonbau sowie die verwandten Fächer. Unter Mitwirkung hervorragender Fachmänner herausgegeben von der Zeitschrift *Beton u. Eisen.* III. Jahrgang, Pts. 1-2. Berlin, Wilhelm Ernst & Sohn, 1907.

Standard Polyphase Apparatus and Systems. By Maurice A. Oudin. Fifth Edition, Revised and Enlarged. New York, D. Van Nostrand Company; London, Sampson Low, Marston & Company, Limited, 1907.

A Handbook of Wireless Telegraphy. Its Theory and Practice, for the Use of Electrical Engineers, Students, and Operators. By James Erskine-Murray. New York, D. Van Nostrand Company; London, Crosby Lockwood and Son, 1907.

A Treatise on the Law of Municipal Ordinances. By Eugene McQuillin, of the St. Louis Bar. Chicago, Callaghan & Company, 1904.

The Sanitary Evolution of London. By Henry Jephson. Brooklyn, N. Y., A. Wessels Company, 1907.

SUMMARY OF ACCESSIONS.

From November 12th to December 9th, 1907.

Donations (including 11 duplicates)	260
By purchase	10
Total	270

MEMBERSHIP.

ADDITIONS.

(November 12th to December 10th, 1907.)

MEMBERS.		Date of Membership.
BALCH, WILLIAM HOYT. Engr., Aberthaw Constr. Co., 8 Beacon St., Boston, Mass..	Assoc. M.	April 1, 1903
	M.	Dec. 3, 1907
BLOSSOM, FRANCIS. Engr. and Contr. (Sanderson & Porter), 52 William St., New York City.....		Dec. 4, 1907
BYERS, ALEXANDER MOSBY CLAYTON. 3*a* Calle Puebla 7, Colonia Condesa, City of Mexico, Mexico.....		Nov. 6, 1907
CLAYTON, THOMAS WILEY. 2655 W. Robey St., Chicago, Ill.		Nov. 6, 1907
FARNUM, LORING NELSON. Gen. Mgr. of Constr., J. G. White & Co., 43 Exchange Pl., New York City.....		Dec. 4, 1907
HERRMANN, FREDERICK CHARLES. Chf. Engr., The California Development Co., Calexico, Cal.....		Nov. 6, 1907
MOISSEIFF, LEON SOLOMON. Asst. Engr., Dept. of Bridges, City of New York, Park Row Bldg., New York City.....	Jun.	Dec. 3, 1895
	Assoc. M.	Sept. 5, 1900
	M.	Dec. 3, 1907
PITZMAN, JULIUS. Surv. and Civ. Engr., 615 Chestnut St., St. Louis, Mo.....		Dec. 4, 1907
ROCKWELL, JAMES VINCENT. Civ. Engr., U. S. N., Navy Yard, Mare Island, Cal.....	Jun.	April 3, 1900
	Assoc. M.	Feb. 4, 1903
	M.	Nov. 5, 1907
ROHRER, JACOB BOMBERGER. Asst. Mgr., American-Hawaiian Eng. & Constr. Co., Ltd., 332 Turk St., San Francisco, Cal.....		Nov. 6, 1907
SMITH, HOWARD EVERETT. Res. Engr., Dept. of State Engr. and Surv., 106 E. First St., Oswego, N. Y.....		Nov. 6, 1907
SUMNER, ROBERT SWAN. 204 Commonwealth Bldg., Denver, Colo.....	Assoc. M.	June 3, 1903
	M.	Nov. 5, 1907
TERRY, JOHN HERMON. Secy. and Treas., Latta & Terry Constr. Co., 1319 Penna. Bldg., Philadelphia, Pa.....		Oct. 2, 1907
VAN ALSTYNE, HENRY ARTHUR. 116 Bay 26th St., Bensonhurst, N. Y.....	Assoc. M.	June 6, 1900
	M.	Dec. 3, 1907

ASSOCIATE MEMBERS.		
ALTSTAETTER, FREDERICK WILLIAM. P. O. Box 1240, Pittsburgh, Pa.....		Nov. 6, 1907
ATWOOD, EDWARD FRANKLIN. 29 Batavia St., Boston, Mass.		June 5, 1907
BASS, FREDERIC HERBERT. 116 Beacon St., Minneapolis, Minn.		Nov. 6, 1907
BATES, WILLIAM BERNARD. City Engr., Roanoke, Va.....		Nov. 6, 1907
BEATTY, PHILIP ASFORDBY. Asst. Engr., B. & O. R. R. Co., 231 E. North Ave., Baltimore, Md.....		Nov. 6, 1907

ASSOCIATE MEMBERS (*Continued*).

		Date of Membership.
BEBB, EDWARD CROSBY. Engr., U. S. Reclamation Service, Glendive, Mont.		Nov. 6, 1907
BEEKMAN, JOHN VAN DERVEER, JR. Boston Mgr., Purdy & Henderson, 101 Tremont St., Boston, Mass.	Jun.	Sept. 3, 1901
	Assoc. M.	July 10, 1907
BENNETT, CHARLES NOBLE. Charleroi, Pa.		Dec. 4, 1907
BOUGHTON, WILL HAZEN. Head of Civ. Eng., Dept. of West Virginia Univ., and Cons. Engr. to the County Court of Monongalia County, W. Va.; Morgantown, W. Va.		Nov. 6, 1907
BRATTON, EDWARD ELISHA. 5034 Cedar Ave., Philadelphia, Pa.		Oct. 2, 1907
CAUTHORN, EDWARD BEAUFORD. City Engr., Columbia, Mo.		June 5, 1907
DIECK, ROBERT GEORGE. Mohawk Bldg., Portland, Ore.		Nov. 6, 1907
DODGE, SAMUEL DOUGLASS. Asst. Engr. with the Board of Water Supply of the City of New York, Cornwall-on-Hudson, N. Y.		Nov. 6, 1907
DONAHEY, JOSEPH ALEXANDER. Res. Engr., L. S. & M. S. R. R., Darrowville, Ohio.		Dec. 4, 1907
ESPENSHADE, EDWARD BOWMAN. Res. Engr., C., M. & St. P. Ry. Co. of Mont., Roundup, Mont.		Nov. 6, 1907
FISCHER, THEODORE CHRISTIAN. 1018 E. Grand St., Elizabeth, N. J.		Dec. 4, 1907
GRISWOLD, HARRY TODD. 67 West 38th St., New York City	Jun.	Oct. 6, 1903
	Assoc. M.	Dec. 4, 1907
HANNA, WALTER SCOTT. Asst. Engr., Pennsylvania Dept. of Health, Harrisburg, Pa.	Jun.	Oct. 6, 1903
	Assoc. M.	June 5, 1907
HATTAN, WILLIAM CARY. Camp No. 2, Altapass, N. C.		Nov. 6, 1907
HOLLEY, CARL HIRAM. Gen. Supt. and Chf. Engr., Mt. Whitney Power Co., Visalico, Cal.		June 5, 1907
LEMEN, WILLIAM CASWELL SMITH. U. S. Engr. Office, Brunswick, Ga.		July 10, 1907
MACDIARMID, MILO STUART. 205 Old P. O. Bldg., Detroit, Mich.		Sept. 4, 1907
MURRAY, RAY. Res. Engr., Poughkeepsie Bridge, Poughkeepsie, N. Y.	Jun.	Oct. 6, 1903
	Assoc. M.	Dec. 4, 1907
OBREITER, JOSEPH WILLIAM. 908 Castle Point Terrace, Hoboken, N. J.		Nov. 6, 1907
PISTOR, GEORGE EMIL JOHN. Designing Engr., Hay Foundry & Iron Works, 114 East 28th St., New York City	Jun.	Dec. 3, 1901
	Assoc. M.	July 10, 1907
PORTER, SAM GRAHAM. Chf. Engr., Arkansas Val. Sugar Beet & Irrigated Land Co., Holly, Colo.		Oct. 2, 1907
QUIMBY, CHARLES HENRY, JR. Res. Engr., N. Y., W. & B. Ry., 220 So. Fulton Ave., Mt. Vernon, N. Y.		Dec. 4, 1907
RICHARDSON, JOHN FRANCIS. U. S. Reclamation Service, Grants Pass, Ore.	Jun.	Oct. 3, 1899
	Assoc. M.	June 5, 1907

ASSOCIATE MEMBERS (*Continued*).

	Date of Membership.
RUGG, WARREN FULLER. 147 Bay St., Peekskill, N. Y.	Nov. 6, 1907
SPIKER, WILLIAM THOMAS CLARE. 145 Westcombe Hill, Blackheath, London, England	June 5, 1907
STEARNS, RALPH HAMILTON. Asst. Engr. Designer, Board of Water Supply, 299 Broadway, New York City	Dec. 4, 1907
STUBBLEFIELD, GARFIELD. Hermiston, Ore	Nov. 6, 1907
SYKES, GEORGE. Bldg. Constr., 1123 Broadway, New York City	Jun. May 1, 1906 Assoc. M. Dec. 4, 1907
WAGNER, HARRY EDWARD. 116 Huntington Ave. Boston, Mass.	Nov. 6, 1907
WASSNER, MICHAEL. Belfast House, Belfast, N. Y.	June 5, 1907
WOODCOCK, HENRY WRIGHT. 263 Fifty-second St., Brooklyn, N. Y.	Jun. Dec. 1, 1903 Assoc. M. Dec. 4, 1907
ZABRISKIE, ALBERT MENGER. 161 E. Front St., Plainfield, N. J.	Dec. 4, 1907

ASSOCIATES.

ANDERSON, ROBERT. 2461 Grandin Rd., Cincinnati, Ohio	Nov. 6, 1907
McBURNEY, HENRY. Draftsman, Am. Bridge Co., Pencoyd Plant, 1409 Locust St., Philadelphia, Pa.	Jun. Jan. 5, 1904 Assoc. Nov. 6, 1907

JUNIORS.

BARKER, JAMES MADISON. Mass. Inst. Tech., Boston, Mass.	Oct. 1, 1907
BENEDICT, NATHAN. Asst. Engr., Changuinola Ry., Bocas del Toro, Panama	Oct. 1, 1907
CANTWELL, HERBERT EDWARD. M. of W. Dept., N. Y. C. & H. R. R., Albany, N. Y.	Dec. 3, 1907
DRIGGS, EDWIN LEROY. Junior Engr., U. S. Reclamation Service, Lujane, Colo	Nov. 5, 1907
GEARHART, HEBER GASSLER. Box 26, Duquesne, Pa	Nov. 5, 1907
HATCH, EVERETT HAMILTON. 717 First St., Napa, Cal	Nov. 5, 1907
LAMB, WILLIAM ALFRED. Sacramento, Cal	Nov. 5, 1907
LEWIS, CHESTER BROOKS. Asst. Engr., Indianapolis Water Co., 113 Monument Pl., Indianapolis, Ind	Nov. 5, 1907
MILLER, FRITZ. Care, Div. Engr., R. G. W. R. R., Salt Lake City, Utah	June 4, 1907
PACE, FULTON. Caldwell, Idaho	Nov. 5, 1907
SCHLICKEISEN, ALBERT AUGUST. Care, Buckley Eng., & Constr. Co., 624 Madison Ave., New York City	Dec. 3, 1907
STOW, MULFORD. Middletown, N. Y.	Sept. 3, 1907
SWETT, EVERETT HAROLD. 78 Woodbine St., Providence, R. I.	Oct. 1, 1907
VAN HORNE, JOHN RUSSELL. 29 Broadway, New York City.	Nov. 5, 1907
WARD, GEORGE MERRITT. Care, J. G. White & Co., Inc., Hatfield, Wis.	Nov. 5, 1907

DEATHS.

Cox, Abraham Beekman. Elected Member, April 1st, 1874; died February, 1906.

Handy, Edward Adino. Elected Member, January 2d, 1889; died November 21st, 1907.

Nelles, George Thomas. Elected Member, October 3d, 1888; died November 15th, 1907.

Rumsey, B. C. Elected Fellow, May 12th, 1870; date of death not known.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(November 12th to December 9th, 1907.)

NOTE.—*This list is published for the purpose of placing before the members of the Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(1) *Journal*, Assoc. Eng. Soc., 31 Milk St., Boston, Mass., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Blk., Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 10c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.

(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 803 Fulton Bldg., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne, England.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Industrial World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.
(70) *Engineering Review*, New York, City, 10c.
(71) *Journal*, Iron and Steel Inst., London, England.
(72) *Electric Railway Review*, Chicago, Ill., 10c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, Ill., 10c.
(77) *Journal*, Inst. Elec. Engrs., London, England.
(78) *Beton und Eisen*, Vienna, Austria.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie-Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Dinglers Polytechnisches Journal*, Berlin, Germany.
(83) *Progressive Age*, New York City, 15c.
(84) *Le Ciment*, Paris, France.
(85) *Proceedings*, Am. Ry. Eng. and M. of W. Assoc., Chicago, Ill.
(86) *Engineering-Contracting*, Chicago, Ill.
(87) *Roadmaster and Foreman*, Chicago, Ill., 10c.
(88) *Bulletin* of the International Ry. Congress Assoc., Brussels, Belgium.

LIST OF ARTICLES.

Bridge.

On Classification of Existing Bridges. A. J. Himes. (85) Vol. 8.
On Maintenance of Existing Metal Bridges. B. W. Guppy. (85) Vol. 8.
Report of Committee of the Amer. Ry. Eng. and M. of W. Assoc. on Wooden Bridges and Trestles.* (85) Vol. 8.
Design for the Henry Hudson Memorial Bridge; a Concrete Rib Arch of 703 Ft. Span.* (13) Nov. 21.
The Long Key Viaduct; Description of a Two-Mile Reinforced Concrete Railway Viaduct.* Wm. Mayo Venable. (14) Nov. 23.
The Manhattan Approach of the Blackwell's Island Bridge.* (14) Nov. 23.
Empiricism and Error in Arch Design. Charles W. Comstock. (13) Nov. 28.
The Phœnixville Testimony in the Quebec Bridge Inquiry. (13) Nov. 28.
Method and Cost of Molding Large Concrete Slabs for Girder Bridges.* (86) Dec. 4.
The Queens Approach to the Blackwell's Island Bridge, New York.* (14) Dec. 7.
Pont Suspendu à Poutres Raidissantes et à Articulation Médiane.* Gisclard. (43) Pt. 3.
Note sur les Travaux de Réfection du Tablier du Pont des Saints-Pères.* Pigeaud. (43) Pt. 3.
Die Neue Rheinbrücke zwischen Ruhrort und Homberg.* (51) Serial beginning Nov. 9.
Die Marienbrücke über den Wiener Donaukanal.* Karl Rosenberg. (53) Serial beginning Nov. 22.

Electrical.

Power Work as Related to Telephone Communications. Thomas Lambert. (4) Oct.
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PAPERS AND DISCUSSIONS.

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OVERHEAD CONSTRUCTION FOR HIGH-TENSION ELECTRIC TRACTION OR TRANSMISSION.

By R. D. Coombs, Assoc. M. Am. Soc. C. E.

To be Presented February 5th, 1908.

A proper regard for the safety of the public, and the great necessity, from an operating standpoint, of uninterrupted service on power-transmission lines and the railroad or other lines they cross, demand the most reliable type of construction.

"Crossing spans," being relatively few in number and relatively great in importance, should be built in the best manner possible, and without the same consideration of cost as that which is proper for a line on private right of way.

The choice of a type of construction for transmission companies, on private right of way, may be said to depend on the cost of construction *versus* the cost of interruptions to service, and maintenance. This is also true, though to a less extent, of certain classes of railroad power lines.

Where transmission-company power lines cross railroads, or when high-tension wires are used by railroads for purposes of electric traction, the cost of failures of construction will be found to exceed the additional cost of good construction.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

Interruptions of service on transmission lines, and accidental contact with other lines, can usually be charged to the following causes:

1st.—Short-circuiting by birds, branches, kites or other objects spanning the wires;
2d.—Burning cross-arms or pins by discharges from the power line;
3d.—Fires burning wooden poles;
4th.—Failures due to lightning;
5th.—Electrical failure of insulators;
6th.—Careless or malicious breaking of insulators;
7th.—Failures due to wind and ice storms, or to floods.

Short-circuiting, while not eliminated, will be reduced as much as appears to be practicable by spacing the wires not less than 30 in. apart and cutting back standing timber from the immediate vicinity of the line.

The burning of pins or poles will be prevented by the use of steel superstructures and metallic pins.

Steel superstructures will not be in danger from lightning, and the addition of a ground wire above the power wires should lessen the likelihood of other lightning troubles on the line.

The electrical failure of insulators is mainly a question of cost.

Malicious injury cannot be guarded against, but may be lessened by a campaign of education.

Mechanical failures, due to storms, may be guarded against in the design; and a properly designed structure may be considered as secure as other forms of steel construction.

Ice Load.—Depending on the climate, allowance must be made for accumulations of sleet upon all wires and superstructures. The latest practice regarding sleet loads varies from no load to a thickness of 1 in. Experience with telephone and telegraph lines indicates that sleet formation ranges from a thin film to a hollow cylinder 2½ in. in diameter and ½ in. thick. It is probable, however, that these large formations are not continuous, or do not remain in place during high winds.

The weight of sleet, particularly the larger formations—which may be partly snow—should be assumed as somewhat less than that of clear ice. It will be noted that a thickness of ½ in. of ice is hereafter

assumed to remain in place during a high wind, the weight being assumed as 0.033 lb. per cu. in.

Wind Loads.—No exact specification for wind pressure has, as yet, been very generally accepted. Perhaps the most common method has been to adopt pressures of from 30 to 50 lb. per sq. ft., as required by bridge specifications, and modify them for cylindrical surfaces. In reality, these wind pressures, as used in bridge practice, include an allowance for vibration, and are not considered as likely to act over extended surfaces.

Since the publication of Sir Isaac Newton's law for the pressures exerted by moving fluids—which, for wind pressures, may be reduced to the form:

$$P = \frac{K}{370} V^2$$

in which P = pressure, in pounds per square foot,
and V = velocity, in miles per hour—

many investigators have experimented, with a view to the determination of values for the constant, K. For normal pressures against thin flat surfaces,* most of the results indicate values between:

$$P = 0.0035\ V^2 \quad \ldots\ldots (1)$$

and

$$P = 0.0049\ V^2 \quad \ldots\ldots (2)$$

These formulas, modified to apply to cylindrical surfaces, become

$$P = 0.0021\ V^2 \quad \ldots\ldots (3)$$

and

$$P = 0.0029\ V^2 \quad \ldots\ldots (4)$$

The Berlin-Zossen high-speed tests, in which wind pressures against trains were measured, gave the formula:

$$P = 0.0027\ V^2$$

and, using a rounded "nose" on the forward end:

$$P = 0.0025\ V^2$$

In 1903-04, at Niagara Falls, Mr. H. W. Buck† conducted a series of tests on a stranded cable having a span of 950 ft. Dynamometers attached to the center of the cable gave direct readings of the wind pressures occurring in conjunction with velocities indicated by a Government standard anemometer, also placed at the center of the span.

The following limiting conditions are to be noted:

The maximum velocity observed was 40 miles per hour (indicated).

* See Report of the Special Army Engineer Board, U. S. War Department, Sept. 29, 1894.

† "The Use of Aluminum as an Electrical Conductor," by H. W. Buck, International Electrical Congress, 1904.

The single anemometer used registered velocities at the center of the span, and gave no indication of the velocities at other points.

It is probable that the stranded cable gave slightly higher results than would be the case with a solid wire.

These tests give the following formula:

$$P = 0.0025\ V^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Omitting from consideration the effects of tornadoes and cyclones, it is necessary to determine, or assume, the maximum velocity of the wind, for general practice or for any particular locality. Many of the results of anemometer tests may be regarded with suspicion, owing to imperfect apparatus, it being very probable that some previously recorded pressures should be reduced from 10 to 25%, to be comparable with those obtained by modern instruments.

Table 1 (U. S. Weather Bureau) shows the equivalent "actual" velocities corresponding to those "indicated" by anemometer readings.

TABLE 1.

Indicated Velocity, in miles per hour.	Actual Velocity, in miles per hour.	Indicated Velocity, in miles per hour.	Actual Velocity, in miles per hour.
0	0.	60	48.0
10	9.6	70	55.2
20	17.8	80	62.2
30	25.7	90	69.2
40	33.3		
50	40.8	*100	*76.2

The records of the United States Weather Bureau—omitting tornadoes, cyclones, and violent gales occurring in some particularly exposed situations—give a maximum indicated velocity of 100 miles per hour. The records at Bidston Observatory (Liverpool, England), from 1884 to 1888, give, as a maximum of ten severe storms, an actual velocity of 78 miles per hour.

Table 2 shows the maximum velocities observed at a number of stations by the United States Weather Bureau:

* Added by comparison.

TABLE 2.

Observatory.	Period.	Maximum Velocity Indicated.	Observatory	Period.	Maximum Velocity Indicated.
Chicago, Ill.	1871–1906	90	Savannah, Ga.	1894–1903	76
Buffalo, N. Y.	1871–1907	90	Philadelphia, Pa.	1872–1907	75
Galveston, Tex.	1894–1903	84	Bismarck, N. Dak.	1894–1903	72
New York, N. Y.	1871–1907	80	Boston, Mass.	1873–1907	72
Eastport, Me.	1873–1907	78	Salt Lake City, Utah.	1894–1903	60

Table 3 shows the three highest indicated velocities recorded by the United States Weather Bureau at the New York City station, in each year, from 1884 to 1906. The station was moved in March, 1895, from the Manhattan Life Building to the present location at 100 Broadway; the latter is evidently a more exposed position, as shown by the abrupt rise in velocities after 1895. The maximum velocity of 80 miles per hour occurred during a sleet storm.

TABLE 3.

Year.	Date.	Maximum Velocity.	Date.	Maximum Velocity.	Date.	Maximum Velocity.
1884	Oct. 18	44	Feb. 20	40	Dec. 9	40
5	Jan. 17	50	Dec. 7	50	Mar. 10	48
6	Feb. 26	64	Mar. 2	54	Jan. 9	44
7	Dec. 29	50	Nov. 16	48	Feb. 12	46
8	Jan. 26	60	Mar. 5	52	Mar. 13	50
9	Jan. 17	50	Feb. 1	48	Dec. 26	48
1890	Jan. 22	55	Dec. 17	48	Feb. 5	45
1	Dec. 30	53	Mar. 14	45	Jan. 11	44
2	Jan. 26	49	Mar. 11	40	Jan. 5	40
3	Aug. 29	54	Jan. 1	48	Oct. 13	48
4	Apr. 11	48	Oct. 10	48	Jan. 12	43
5	Dec. 27	73	Mar. 28	64	Aug. 4	62
6	Mar. 4	72	Feb. 7	65	Sep. 30	56
7	Jan. 18	60	Feb. 6	60	Oct. 17	60
8	Dec. 4	78	Sep. 7	72	Nov. 11	65
9	Mar. 20	80	Jan. 25	66	Feb. 27	64
1900	Oct. 16	76	Nov. 21	76	Jan. 26	76
1	Nov. 26	72	Jan. 19	72	Feb. 5	70
2	Mar. 19	74	Jan. 1	74	Feb. 2	74
3	July 2	72	Feb. 5	72	Sep. 17	65
4	Apr. 16	73	Sep. 15	68	Mar. 3	65
5	Dec. 10	64	Feb. 7	61	Apr. 10	56
6	Mar. 10	64	Jan. 6	61	Feb. 28	59

Table 4 is a record, by months, of the number of different 12-hour periods during which a maximum velocity of 60 miles, or more, was observed at the New York City station, from 1895 to 1906, inclusive. Inasmuch as a maximum occurring late in one period and another early in the following period are both entered, a few of the entries represent the effects of the same storm.

Tables 3 and 4 indicate that, for the vicinity of New York City:

The maximum velocities occur during the winter months, when sleet may be on the wires.

Indicated velocities of more than 80 miles per hour will rarely, if ever, occur during the life of a given structure.

Indicated velocities of from 65 to 75 miles per hour may be expected several times each year, though much less frequently in conjunction with sleet.

TABLE 4.

Month.	Indicated Velocities, in miles per hour:																Totals.
	60	61	62	63	64	65	66	67	68	70	72	73	74	76	78	80	
Jan.	3	3	....	2	2	1	4	....	....	....	1	....	1	1	....	....	18
Feb.	7	2	2	1	6	2	2	2	2	3	1	....	1	....	....	....	31
Mar.	3	....	1	2	2	1	1	....	1	1	3	....	1	....	....	1	17
Apr.	....	1	....	1	....	....	....	....	....	....	....	1	....	....	....	....	3
May	1	....	1	....	1	....	....	....	....	....	....	....	....	....	....	....	3
June.	1	....	....	....	....	....	1	....	....	....	1	....	....	....	....	....	3
July.	....	....	....	....	....	2	1	....	....	....	1	....	....	....	....	....	4
Aug	....	....	1	....	1	....	....	....	....	....	....	....	....	1	....	....	3
Sept.	....	....	....	1	1	2	....	....	1	....	1	....	....	....	....	....	6
Oct.	1	1	....	....	....	....	....	....	....	....	....	....	....	1	....	....	3
Nov.	4	....	2	....	2	1	....	....	....	....	1	1	1	1	....	....	13
Dec.	6	1	1	2	3	1	....	....	1	....	1	1	....	....	1	....	18
Totals.	26	8	8	9	18	10	9	2	5	4	10	3	4	4	1	1	122

Assuming an indicated velocity of 100 miles per hour, or an actual velocity of 76.2 miles per hour, Equations 3 and 4 become:

$$P = 12.19 \text{ lb. per sq. ft. of projected area} \quad (6)$$

and $$P = 16.84 \text{ lb. per sq. ft. of projected area} \quad (7)$$

while Equation 5 becomes:

$$P = 14.51 \text{ lb. per sq. ft. of projected area} \quad (8)$$

Equation 8 is a mean of Equations 6 and 7.

On long spans, the maximum pressure at one point may be considerably in excess of the equivalent uniform pressure along the wire, while very short spans may be exposed to the maximum pressure throughout their length. In the absence of a formula in which the length of span enters as a factor, Equation 5 may be regarded as approximately correct.

In view of the rare, if not improbable, occurrence of velocities greater than 90 miles per hour, "indicated," and the further improbability of such winds accompanying sleet storms, or of the sleet remaining in place, Equations 9 and 10 seem to be reasonable for general use.

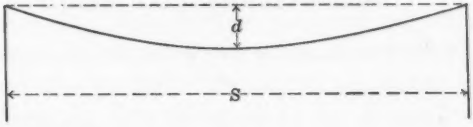
P = 12 lb. per sq. ft. of projected area of bare wires..... (9)

P = 8 lb. per sq. ft. of projected area + ½ in. thickness of ice..(10)

Catenary Stresses.

The following mathematical treatment is not new, but the writer has found the arrangement convenient:

Ends of Span at Same Elevation.



S = span, in feet,
d = sag, in feet,
W = load per linear foot in plane of wire,
A = area of wire, in square inches.
E = modulus of elasticity,
θ = coefficient of expansion,
t = change of temperature, in degrees,
e = elongation or change of length, within elastic limit.
L_o = length, in feet, of imaginary wire ($W = o$) at normal temperature.
L_{oc} = length, in feet of imaginary wire, cold (80° fahr. below normal temperature).
L_{oh} = length, in feet, of imaginary wire, hot (70° fahr. above normal temperature).

Index to subscripts.—

No subscript = normal conditions,
$_c$ = cold: 80° fahr. below normal + dead load,
$_i$ = cold: ice load + dead load,
$_{cw}$ = cold: wind load + dead load,
$_{iw}$ = cold: ice + wind + dead load,
$_h$ = hot: 70° fahr. above normal + dead load.

W_{iw} is the resultant of the vertical dead + ice loads and the horizontal wind load.

W_{cw} is the resultant of the vertical dead load and the horizontal wind load.

Stresses.—Substitute normal values in Equations 1, 2, 3, and 4. Assume values of T_h, T_{iw}, T_c, T_i, or T_{cw}, such that Equations 5 and 6

will give identical values of d_h, d_{iw}, etc. The tension that will give the same sag by Equations 5 and 6 (independently) is the tension resulting from that sag and the given loading.

$$T = \frac{W S^2}{8 d} \quad \ldots\ldots (1)$$

$$L = S\left[1 + \frac{8 d^2}{3 S^2}\right] \quad \ldots\ldots (2)$$

$$e = \frac{T L}{E A} \quad \ldots\ldots (3)$$

$$L_o = L - e \quad \ldots\ldots (4)$$

(70° fahr. above normal, with dead load.)

$$L_{oh} = L_o (1 + \theta t_h) \qquad e_h = \frac{L_{oh} \times T_h}{E A} \qquad L_h = L_{oh} + e_h$$

$$d_h = 0.612 \sqrt{S (L_h - S)} \quad \ldots\ldots (5)$$

$$d_h = \frac{W_h \times S^2}{8 T_h} \quad \ldots\ldots (6)$$

(80° fahr. below normal, with dead + ice + wind loads.)

$$L_{oc} = L_o (1 - \theta t_c) \qquad e_{iw} = \frac{L_{oc} \times T_{iw}}{E A} \qquad L_{iw} = L_{oc} + e_{iw}$$

$$d_{iw} = 0.612 \sqrt{S (L_{iw} - S)} \quad \ldots\ldots (5)$$

$$d_{iw} = \frac{W_{iw} \times S^2}{8 T_{iw}} \quad \ldots\ldots (6)$$

(80° fahr. below normal, with dead load.)

$$L_{oc} = L_o (1 - \theta t_c) \qquad e_c = \frac{L_{oc} \times T_c}{E A} \qquad L_c = L_{oc} + e_c$$

$$d_c = 0.612 \sqrt{S (L_c - S)} \quad \ldots\ldots (5)$$

$$d_c = \frac{W_c \times S^2}{8 T_c} \quad \ldots\ldots (6)$$

(80° fahr. below normal, with dead + ice loads.)

$$L_{oc} = L_o (1 - \theta t_c) \qquad e_i = \frac{L_{oc} \times T_i}{E A} \qquad L_i = L_{oc} + e_i$$

$$d_i = 0.612 \sqrt{S (L_i - S)} \quad \ldots\ldots (5)$$

$$d_i = \frac{W_i \times S^2}{8 T_i} \quad \ldots\ldots (6)$$

(80° fahr. below normal, with dead + wind loads.)

$$L_{oc} = L_o (1 - \theta t_c) \qquad e_{cw} = \frac{L_{oc} \times T_{cw}}{E A} \qquad L_{cw} = L_{oc} + e_{cw}$$

$$d_{cw} = 0.612 \sqrt{S (L_{cw} - S)} \quad \ldots\ldots (5)$$

$$d_{cw} = \frac{W_{cw} \times S^2}{8 T_{cw}} \quad \ldots\ldots (6)$$

TABLE 5.—STRANDED WIRE—STEEL (Galvanized).

Diameter.	No. and Gauge of Wires.	Area, in square inches.	Ultimate Strength.		
			Siemens-Martin, 75 000 lb.	High-tension, 125 000 lb.	Extra high tension, 187 000 lb.
$\frac{5}{8}$ in.	7— 5	0.2356	19 000	25 000	42 000
$\frac{9}{16}$ "	7— $6\frac{1}{2}$	0.1922	14 500	21 100	34 500
$\frac{1}{2}$ "	7— 8	0.1443	11 000	18 000	27 000
$\frac{7}{16}$ "	7— 9	0.1204	9 000	15 000	22 500
$\frac{3}{8}$ "	7—11	0.0832	6 800	10 500	17 250
$\frac{5}{16}$ "	7—12	0.0606	4 860	8 100	12 100
$\frac{9}{32}$ "	7—$12\frac{3}{4}$	0.0496	4 380	7 300	10 900
$\frac{1}{4}$ "	7—$13\frac{1}{2}$	0.0379	3 050	5 100	7 600
$\frac{7}{32}$ "	7—15	0.0293	2 500	4 100	6 100
$\frac{3}{16}$ "	7—16	0.0218	2 000	3 300	4 900
$\frac{5}{32}$ "	7—$17\frac{1}{4}$	0.0149	1 350	2 230	3 300
$\frac{1}{8}$ "	7—19	0.0097	900	1 500	2 250

Diameter.	Load per Linear Foot (Vertical).		Pressure per Linear Foot (Horizontal).		Load per Linear Foot (Plane of Resultant).	
	Dead.	Dead + ½ in. of ice	At 8 lb. per sq. ft.	At 15 lb. per sq. ft.	Wind, at 8 lb.	Wind, at 15 lb.
			½ in. of ice.	½ in. of ice.	½ in. of ice.	½ in. of ice.
$\frac{5}{8}$ in.	.....	.....	1.250	2.344	.....	.....
$\frac{9}{16}$ "	.....	.....	1.208	2.266	.....	.....
$\frac{1}{2}$ "	.....	.....	1.167	2.188	.....	.....
$\frac{7}{16}$ "	.....	.....	1.125	2.109	.....	.....
$\frac{3}{8}$ "	.....	.....	1.083	2.031	.....	.....
$\frac{5}{16}$ "	.....	.....	1.042	1.953	.....	.....
$\frac{9}{32}$ "	0.510	1.132	1.000	1.875	1.510	2.190
$\frac{1}{4}$ "	0.415	0.998	0.958	1.797	1.383	2.055
$\frac{7}{32}$ "	0.295	0.839	0.917	1.719	1.243	1.913
$\frac{3}{16}$ "	0.210	0.715	0.875	1.641	1.130	1.790
$\frac{5}{32}$ "	0.144	.....	0.854	1.602	.....	.....
$\frac{1}{8}$ "	0.125	0.592	0.833	1.563	1.022	1.671
$\frac{9}{32}$ "	0.095	0.542	0.812	1.523	0.976	1.617
$\frac{7}{32}$ "	0.075	0.503	0.792	1.484	0.938	1.567
$\frac{5}{32}$ "	0.055	0.463	0.771	1.445	0.899	1.517
$\frac{1}{8}$ "	0.032	0.421	0.750	1.406	0.860	1.468

TABLE 6.—SOLID WIRE—COPPER (Hard-Drawn).

Gauge, B. & S.	Diameter, in inches.	Area, in square inches.	Area, in circular mils.	Ultimate strength, in pounds.	Factor of safety = 2½.
0 000	0.4600	0.1662	211 600	8 310	3 325
000	0.4096	0.1318	167 800	6 590	2 635
00	0.3648	0.1045	133 080	5 220	2 090
0	0.3249	0.0829	105 530	4 560	1 825
1	0.2893	0.0657	83 690	3 740	1 495
2	0.2576	0.0521	66 370	3 120	1 250
3	0.2294	0.0413	52 630	2 480	990
4	0.2043	0.0328	41 740	1 960	785
5	0.1819	0.0260	33 100	1 560	625
6	0.1620	0.0206	26 250	1 240	495
7	0.1443	0.0163	20 820	980	390
8	0.1285	0.0130	16 510	780	310
9	0.1144	0.0103	13 090	620	250
10	0.1019	0.0082	10 380	490	195
11	0.0907	0.0065	8 230	390	155
12	0.0808	0.0051	6 530	305	120
13	0.0720	0.0041	5 180	245	100
14	0.0641	0.0031	4 110	185	75

Gauge, B. & S.	Load per Linear Foot (Vertical).		Pressure per Linear Foot (Horizontal).		Load per Linear Foot (Plane of Resultant).	
	Dead.	Dead + ½ in. of ice.	At 8 lb. per sq. ft. ½ in. of ice.	At 15 lb. per sq. ft. ½ in. of ice.	Wind, at 8 lb. ½ in. of ice.	Wind, at 15 lb. ½ in. of ice.
0 000	0.641	1.238	0.973	1.824	1.575	2.205
000	0.509	1.074	0.940	1.762	1.427	2.064
00	0.403	0.940	0.910	1.706	1.309	1.948
0	0.320	0.833	0.883	1.656	1.214	1.854
1	0.253	0.744	0.860	1.612	1.137	1.775
2	0.202	0.673	0.838	1.572	1.075	1.710
3	0.159	0.613	0.820	1.537	1.024	1.655
4	0.126	0.564	0.803	1.505	0.981	1.607
5	0.100	0.524	0.788	1.477	0.946	1.567
6	0.079	0.491	0.775	1.453	0.917	1.534
7	0.063	0.464	0.763	1.430	0.893	1.503
8	0.050	0.441	0.752	1.411	0.872	1.479
9	0.039	0.421	0.743	1.393	0.854	1.456
10	0.032	0.406	0.735	1.377	0.840	1.436
11	0.025	0.392	0.727	1.363	0.826	1.418
12	0.020	0.381	0.721	1.351	0.815	1.404
13	0.016	0.372	0.715	1.340	0.806	1.391
14	0.012	0.363	0.709	1.330	0.796	1.379

Ultimate strength = 50 000 to 60 000 lb. per sq. in
Modulus of elasticity = E = 16 000 000
Coefficient of expansion = θ = 0.0000096

TABLE 7.—STRANDED WIRE—COPPER (Hard-Drawn).

Gauge, B. & S.	Diameter, in inches.	Area, in square inches.	Area, in circular mils.	Ultimate strength, in pounds.	Factor of safety = 2½.
	0.999	0.5892	750 000	.....	.....
	0.963	0.5495	700 000	.....	.....
	0.927	0.5102	650 000	.....	.....
	0.891	0.4715	600 000	.....	.....
	0.855	0.4318	550 000	.....	.....
	0.819	0.3924	500 000	.....	.....
	0.770	0.3523	450 000	.....	.....
	0.728	0.3141	400 000	.....	.....
	0.679	0.2750	350 000	.....	.....
	0.630	0.2360	300 000	.....	.....
	0.590	0.1965	250 000	.....	.....
0 000	0.530	0.1662	211 600	9 970	3 990
000	0.470	0.1318	167 800	7 910	3 160
00	0.420	0.1045	133 080	6 270	2 510
0	0.375	0.0829	105 530	4 970	1 990
1	0.330	0.0657	83 690	3 940	1 580
2	0.291	0.0521	66 370	3 130	1 250
3	0.261	0.0413	52 630	2 480	990
4	0.231	0.0328	41 740	1 970	790

Circular mils, or B. & S. gauge.	Load per Linear Foot (Vertical).		Pressure per Linear Foot (Horizontal).		Load per Linear Foot (Plane of Resultant).	
	Dead.	Dead + ½ in. of ice.	At 8 lb. per sq ft ½ in. of ice.	At 15 lb. per sq. ft. ½ in. of ice.	Wind, at 8 lb. ½ in. of ice.	Wind. at 15 lb. ½ in. of ice.
750 000	2.288	3.220	1.333	2.499	.....	.....
700 000	2.135	3.045	1.309	2.454	.....	.....
650 000	1.983	2.871	1.285	2.409	.....	.....
600 000	1·830	2.695	1.261	2.364	.....	.....
550 000	1.678	2.521	1.237	2.319	.....	.....
500 000	1.525	2.345	1.213	2.274	.....	.....
450 000	1.373	2.163	1.180	2.213	.....	.....
400 000	1.250	1.984	1.152	2.160	.....	.....
350 000	1.068	1.801	1.119	2.099	.....	.....
300 000	0.915	1.618	1.087	2.038	.....	.....
250 000	0.762	1.440	1.060	1.988	.....	.....
0 000	0.645	1.286	1.020	1.913	1.641	2.305
000	0.513	1.116	0.980	1.838	1.485	2.150
00	0.406	0.978	0.947	1.775	1.361	2.026
0	0.322	0.866	0.917	1.719	1.261	1.925
1	0.255	0.771	0.887	1.663	1.175	1.833
2	0.203	0.695	0.861	1.614	1.107	1.757
3	0.160	0.633	0.841	1.576	1.053	1.698
4	0.127	0.582	0.821	1.539	1.006	1.645

Ultimate strength = 60 000 lb. per sq. in.

TABLE 8.—Stranded Wire—Aluminum.

Gauge, B. & S.	Diameter, in inches.	Area, in square inches.	Area, in circular mils.	Ultimate strength, in pounds.	Elastic limit.	Factor of safety = 2½.		
	1.035	.....	800 000	.....	60%	.....	23 000 lb. per sq. in.	37 wires.
	0.996	0.5892	750 000	13 550	.....	5 420		
	0.963	0.5495	700 000	12 640	.....	5 050		
	0.928	0.5102	650 000	11 730	.....	4 690		
	0.891	0.4715	600 000	10 840	.....	4 340		
	0.854	0.4318	550 000	9 930	.....	3 970		
	0.814	0.3924	500 000	9 025	.....	3 610		
	0.772	0.3523	450 000	8 100	.....	3 240	" "	19 wires.
	0.725	0.3141	400 000	7 225	.....	2 890		
	0.679	0.2750	350 000	6 325	.....	2 530		
	0.621	0.2360	300 000	5 430	.....	2 170		
	0.567	0.1965	250 000	4 520	.....	1 810	" "	7 wires.
0 000	0.522	0.1662	.....	3 820	.....	1 530		
000	0.464	0.1318	.....	3 160	65%	1 265	24 000 lb. per sq. in.	
00	0.414	0.1045	.....	2 510	.....	1 000		
0	0.368	0.0829	.....	1 990	.....	795		
1	0.328	0.0657	.....	1 575	.....	630		
2	0.291	0.0521	.....	1 250	.....	500		
3	0.261	0.0413	.....	990	.....	395		
4	0.231	0.0328	.....	790	.....	315		

Circular mils, or B. & S. gauge.	Load per Linear Foot (Vertical).		Pressure per Linear Foot (Horizontal).		Load per Linear Foot (Plane of Resultant).	
	Dead.	Dead + ½ in. of ice.	At 8 lb. per sq. ft. ½ in. of ice.	At 15 lb. per sq. ft. ½ in. of ice.	Wind, at 8 lb. ½ in. of ice.	Wind, at 15 lb. ½ in. of ice.
800 000	0.736	1.691	1.357	2.544	.....	.....
750 000	0.690	1.620	1.331	2.495	.....	.....
700 000	0.644	1.554	1.309	2.454	.....	.....
650 000	0.598	1.486	1.285	2.410	.....	.....
600 000	0.552	1.417	1.261	2.364	.....	.....
550 000	0.506	1.348	1.236	2.318	.....	.....
500 000	0.460	1.278	1.209	2.268	.....	.....
450 000	0.414	1.205	1.181	2.215	.....	.....
400 000	0.368	1.130	1.150	2.156	.....	.....
350 000	0.322	1.055	1.119	2.099	.....	.....
300 000	0.276	0.973	1.081	2.026	.....	.....
250 000	0.230	0.894	1.045	1.959	.....	.....
0 000	0.195	0.831	1.015	1.902	1.312	2.075
000	0.155	0.755	0.976	1.830	1.234	1.979
00	0.122	0.691	0.943	1.768	1.168	1.898
0	0.097	0.637	0.912	1.710	1.112	1.825
1	0.077	0.592	0.885	1.660	1.065	1.762
2	0.061	0.553	0.861	1.614	1.023	1.706
3	0.049	0.522	0.841	1.576	0.990	1.660
4	0.039	0.494	0.821	1.539	0.958	1.616

Ultimate strength = 23 000 to 24 000 lb. per sq. in.
Modulus of elasticity = E = 9 000 000.
Coefficient of expansion = θ = 0.0000128.

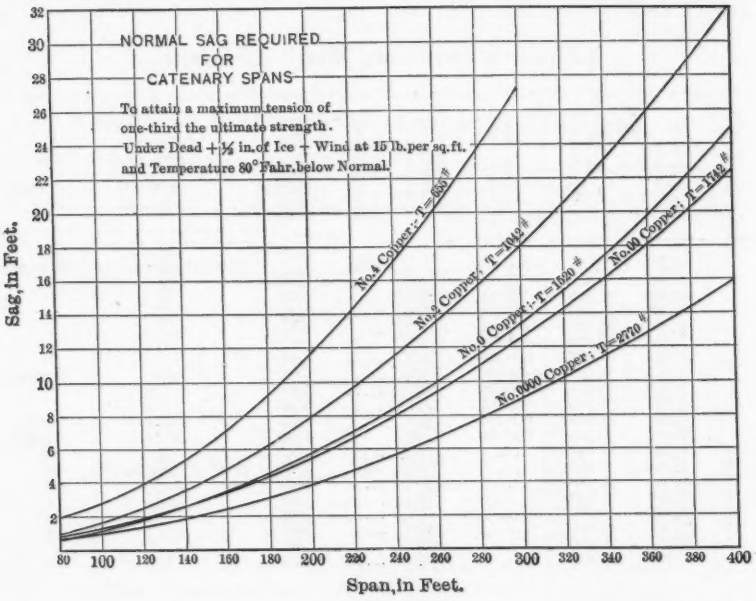


FIG. 1.

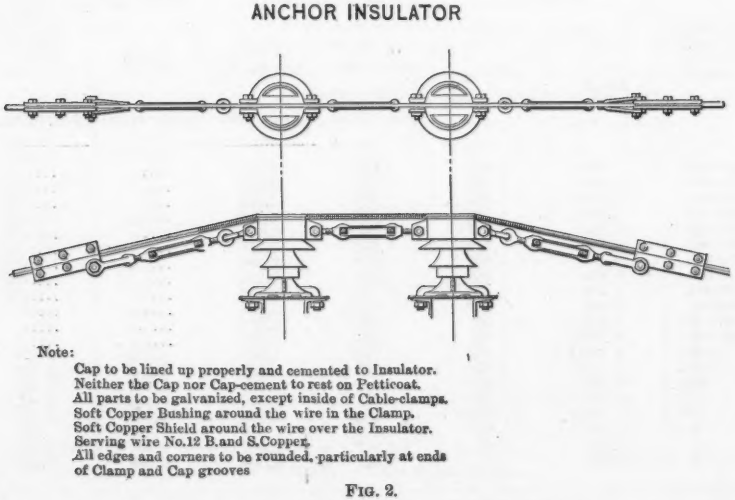


FIG. 2.

Fig. 1 shows a set of curves giving the approximate normal sags required for hard-drawn, solid, copper wire, when the maximum tension is limited to one-third the ultimate strength.

Figs. 2 and 3 show two types of anchor insulators, in which two or more insulators withstand the tension of the span, and in which an auxiliary attachment is provided in case of failure at the insulator.

ANCHOR INSULATOR

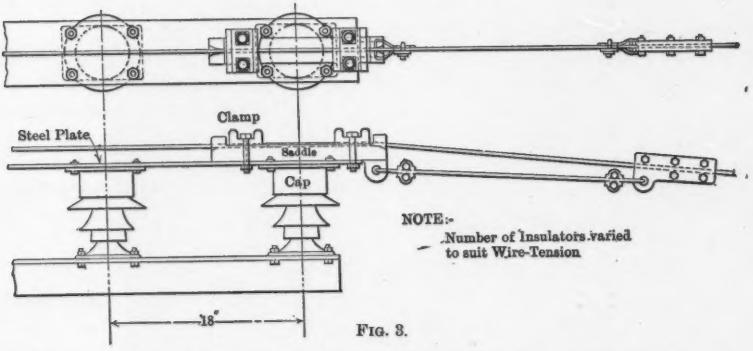


FIG. 3.

SPECIFICATIONS FOR OVERHEAD CONSTRUCTION OF HIGH-TENSION TRANSMISSION-LINE CROSSINGS.

General Requirements.

Drawings.—Complete drawings shall be furnished, in duplicate, for approval before construction is commenced.

General drawings shall contain full information covering stresses, span, normal sag, size and material of wires or cables, voltage, elevation of the points of support from the top of the rail, and the maximum sag and subsequent clearance above the top of the rail.

Detailed plans, covering insulators, pins, clamps, etc., and their supporting construction and foundations, shall be furnished for approval.

After approval, (.....) complete sets of drawings shall be furnished for file, and, when the construction is at the expense of the Railroad Company, the original tracings shall be forwarded for file.

Clearance.—The clear distance of any part of the construction from the center line of the track, and the clear head-room above the top of the rail, shall be as specified by the proper official of the Railroad Company, but the clear head-room shall not be less than 30 ft. nor less than 6 ft. above any existing wires, such clearance to obtain under the maximum deflection due to loads and temperature.

Minimum spread of wires.....30 in.
Minimum side or top clearance between wires and superstructure.15 in.
Minimum side clearance between insulators and superstructure.. 8 in.

Spans.—The spans immediately adjoining the crossing span shall be slack spans. Poles or towers at the ends of crossing spans and slack spans shall be self-supporting, or be guyed so as to be in effect self-supporting. Double cross-arms (or an approved substitute), insulators, clamps, etc., at the ends of crossing spans and slack spans shall be designed so as to prevent the wires from pulling through in case of failure in an adjoining span or at the support.

Condition of Loading.—The structure shall be designed to withstand, with the allowable factor of safety, the combined effect of the dead, ice and wind loads, and be self-sustaining under the following conditions of loading:

(1) Dead + ice + wind on adjoining spans.
(2) Dead + ice + wind on one span and dead load on adjoining span.

Loads.—

Dead load, or weight of the material;

Ice load: Weight of ice $\frac{1}{2}$ in. thick all around exposed members. Weight of ice, 0.033 lb. per cu. in.

Wind load: Wind pressure on wires or other cylindrical surface, 15 lb. per sq. ft. of projected area, such area being taken at the increased figure due to ice $\frac{1}{2}$ in. thick.

Pressure on flat surfaces, 27 lb. per sq. ft.

Factors of Safety.—Factors of safety, under the combination of loads giving the maximum stress, shall be as follows:

Wires and cables	$2\frac{1}{2}$
Insulators, pins, clamps, steel cross-arms and connections	3
Steel superstructure	$2\frac{3}{4}$
Wooden superstructure and cross-arms	5

Temperature.—In the determination of stresses and clearances, and in erection, provision shall be made for a change in temperature of 70° fahr, above and 80° fahr. below a normal temperature of 60° fahr.

Thickness of Material.—All metal in the superstructure shall be not less than $\frac{1}{4}$ in. in thickness.

Radius of Gyration.—The length of any compression member shall not exceed 150 times its least radius of gyration.

Connections.—Connections, generally, shall develop the full strength of the member, and shall be designed to avoid, as far as possible, induced stresses due to eccentricity.

Net Section.—In calculating tensile stresses, allowance shall be made for reduction in area, due to rivet holes (adding $\frac{1}{8}$ in. to the nominal diameter), screw threads, etc.

Rivets.—Rivets shall be machine-driven, wherever practicable. Loose or defective rivets shall be carefully cut out and replaced; if

necessary, to avoid injuring the material, they shall be drilled out. The diameter of the finished rivet hole shall not be more than $\frac{1}{16}$ in. greater than the diameter of the cold rivet.

Bolts.—Bolts shall not be used in place of rivets, except as specified; and when used, the holes shall be reamed and the bolts made to a close fit.

Straightening.—All material, when necessary, shall be carefully straightened at the shop before assembling.

Drainage.—Pockets, such as enclosed column footings, shall have drain holes, and shall be filled with water-proof material (or concrete), or both, as may be required.

Galvanizing.—Messenger and guy wires, insulator pins, clamps, etc., shall be galvanized. Structural-steel poles shall be galvanized in an approved manner, or shall be painted, as provided below.

Painting.—Structural steel shall be thoroughly cleaned at the shops and given one good coat of linseed oil. All surfaces coming in contact in assembling shall be given one coat of approved paint. Parts which will be inaccessible after erection shall receive two shop coats of approved paint. All machined surfaces shall be coated with white lead and tallow. After erection, all steel shall be given two coats of approved paint. Painting shall not be done during rainy weather, or when the surface of the metal is wet. All dirt, cinders, oil blisters, etc., shall be removed before painting.

Weight.—A variation, in section or weight of materials, of more than 2½% will be sufficient cause for rejection, except that sheared plates may vary according to the allowances of the Manufacturers' Standard.

Foundations.—The foundations shall be designed to resist overturning, assuming:

Weight of "earth"	90 lb. per cu. ft.
" " "concrete"	140 " " " "
Angle of friction of "earth"	33° with vertical.

Foundations, in general, shall extend above the ground as a protection to the lower part of the structure; otherwise, the depth and spread of foundations shall be governed by the local conditions.

Guys.—Guy wires shall have an efficient anchorage, and be protected, or of extra strength, at the ground level.

Cradles.—Cradles are not to be furnished, but the crossing shall be designed for their possible future installation.

Timber.—All timber shall be of the best quality of the kind and use specified, cut from sound trees, and sawed to size; close-grained and solid, and out of wind; free from defects, such as injurious ring shakes, crooked grain, large, unsound or loose knots, knots in groups, decay, large pitch pockets or other defects which would materially impair its strength.

TABLE 9.—UNIT STRESSES IN MATERIALS, IN POUNDS PER SQUARE INCH.

Material.	Tension.	Compression.	Shear.	Bearing.	Bending.	Compression with the grain.	Compression across the grain.	Transverse shear.	Longitudinal shear.	Columns.
Soft steel	19 000	$\left\{\begin{matrix}19\,000 \\ -65\,\frac{l}{r}\end{matrix}\right\}$	12 500	.....	.....	.....	.....	.....	.....	.....
Medium steel	22 000	$\left\{\begin{matrix}22\,000 \\ -80\,\frac{l}{r}\end{matrix}\right\}$	14 500	.....	.....	.....	.....	.....	.....	.....
Shop rivets and pins	.....	.....	12 000	24 000	.....	.....	.....	.....	.....	.....
Field rivets and bolts	.....	.....	9 000	18 000	.....	.....	.....	.....	.....	.....
Pins	.....	.....	.....	.....	24 000	.....	.....	.....	.....	.....
Long-leaf yellow pine	.....	.....	.....	.....	1 200	1 400	300	1 000	150	$\left\{\begin{matrix}1\,200 \\ -18\,\frac{L}{D}\end{matrix}\right\}$
Oak	.....	.....	.....	.....	1 200	1 400	400	800	16	$\left\{\begin{matrix}1\,000 \\ -15\,\frac{L}{D}\end{matrix}\right\}$
Chestnut	.....	.....	.....	.....	1 000	1 000	180	300	120	$\left\{\begin{matrix}800 \\ -10\,\frac{L}{D}\end{matrix}\right\}$
Cedar	.....	.....	.....	.....	950	1 000	150	300	.....	$\left\{\begin{matrix}800 \\ -12\,\frac{L}{D}\end{matrix}\right\}$

TABLE 10.—COMPOSITION, ETC., OF STEEL AND IRON.

Kind of Steel, etc.	Phosphorus, in acid steel, not more than	Phosphorus, in basic steel, not more than	Sulphur, not more than	Ultimate strength, in pounds per square inch.	Elastic limit Percentage	Minimum elongation in 8 in. Percentage.	Minimum reduction in area. Percentage.	Bending.
Medium, open-hearth, structural steel...	0.06%	0.04%	0.05%	60 000 to 68 000	50	22	50	180° cold.
Soft, open-hearth structural steel.....	0.06%	0.04%	0.05%	52 000 to 60 000	50	25	50	cold, 180° flat.
Rivet steel.....	.....	0.04%	0.04%	48 000 to 56 000	55	28	56	quenched, 180°
Open-hearth cast steel, annealed.....	0.08%	0.05%	0.05%	65 000 Minimum.	50	in 2 in. 15	20	cold, 90° diameter = thickness × 3
Cast iron.....	.....	.....	0.10%	See note*	....	.....	....	.....

* Cast iron, unless otherwise specified, shall be tough, gray iron. It shall be free from flaws and excessive shrinkage. Tests on the "Arbitration Bar" (1¼ in., circular, and 15 in. long), with supports 12 in. apart, shall show a deflection of 0.10 in. for a center load of 2 900 lb.

Each wooden pole or tower shall be set in a concrete base.

Poles shall be of the first quality, with a minimum diameter of 7 in. at the top, and within the following limits of wind:

30 to 40 ft. long—not more than 3 in.
40 to 50 " " — " " " 4 "
50 to 60 " " — " " " 5 "
60 ft. and longer— " " " 6 "

Cross-arms, bearing surfaces, and the surfaces of notches, etc., shall be treated with paint or preservative.

Adjustment.—The sag given the catenaries at erection shall be adjusted to the temperature of the wires, that is, it shall be that corresponding to the dead-load tension of the given span at the temperature of the wires. Particular care shall be exercised in adjusting insulators, clamps, etc., to obtain the desired distribution of stresses.

Workmanship.—The workmanship on the various classes of construction involved shall conform to the requirements of first-class practice.

Insulators.—One or more insulator units, as may be required, shall be assembled complete and mechanically tested to destruction. Insulators shall be tested in accordance with special instructions to be given. Insulators or caps shall not be connected during freezing temperatures.

Reasonable notices of the proposed tests shall be given the ..... and his representative shall be given every facility for witnessing them.

In all cases full test reports shall be forwarded.

Concrete.

The proportions of the materials in the concrete shall be as called for on the drawings, and the proportioning and methods of mixture shall be as required by the Engineer.

Cement.—All cement used in the work shall be of an approved brand of Portland cement. The specific gravity of the cement, thoroughly dried at 100° cent., shall not be less than 3.10. It shall leave, by weight, a residue of not more than 8% on the No. 100 and not more than 25% on the No. 200 sieve.

It shall develop initial set in not less than 30 min., but must develop hard set in not less than 1 hour nor more than 10 hours.

Tensile Strength.—The minimum requirements for tensile strength for briquettes 1 in. square in section shall be within the following limits, and shall show no retrogression in strength within the periods specified:

Neat cement:

24 hours in moist air.....150 to 200 lb.
7 days (1 day in moist air, 6 days in water) 450 to 550 "
28 days (1 day in moist air, 27 days in water) .....550 to 650 "

One part cement, three parts sand:

7 days (1 day in moist air, 6 days in water) 150 to 200 lb.
28 days (1 day in moist air, 27 days in water) .....200 to 300 "

Constancy of Volume.—Pats of neat cement about 3 in. in diameter, ½ in. thick at the center and tapering to a thin edge, shall be kept in moist air for a period of 24 hours.

(*a*)—A pat is then kept in air at normal temperature and observed at intervals for at least 28 days.

(*b*)—Another pat is kept in water maintained as near 70° fahr. as practicable, and observed at intervals for at least 28 days.

(*c*)—A third pat is exposed in any convenient way in an atmosphere of steam, above boiling water, in a loosely-closed vessel, for 5 hours.

These pats, to pass the requirements satisfactorily, shall remain firm and hard, and shall show no sign of distortion, checking, cracking or disintegrating.

Sulphuric Acid and Magnesia.—The cement shall not contain more than 1.75% of anhydrous sulphuric acid (SO_3), nor more than 4% of magnesia (MgO).

Sand.—All sand shall be hard, clean, coarse and sharp, and shall not contain more than 1.5% of clay or other foreign matter. If required by the Engineer, it shall be screened.

Stone.—All stone shall be sound, hard, and durable, and free from dirt and foreign matter, and shall pass through a ring 1½ in. in diameter.

Consistency.—The degree of moisture for mortar, grout and concrete shall be as required by the Engineer; in general, mortar shall be plastic, grout fluid, and concrete of such consistency that it will quake when being deposited.

Mortar, grout, or concrete which has commenced to set shall not be used in the work.

Placing.—Concrete shall be deposited in the work so that there shall be no separation of mortar or stone. It shall be laid quickly in layers, and spaded as may be required. Rock surfaces shall be thoroughly cleaned, and earth surfaces shall be compacted in a satisfactory manner, before concrete is deposited against them. Surfaces of concrete against which fresh concrete is to be laid shall be cleaned and slushed over with grout, and shall be provided with a bond if required by the Engineer.

Forms.—Forms shall be of substantial construction, and designed to preserve the concrete in the form required by the drawings. All exposed surfaces of concrete shall be true to form and surface.

General Clauses.

1.—Every facility for the inspection of materials and workmanship shall be furnished by the contractor; he shall furnish proper testing apparatus, and shall prepare and test such specimens as may be required.

2.—All work shall be subject to the inspection and approval of the Railroad Company's Engineer, and his interpretations of the drawings and specifications, and his decisions as to the quantity or quality of the work, shall be final and conclusive.

3.—The contractor shall remove all falsework, timber, or rubbish incident to his operations, and shall leave the site unobstructed and clean.

4.—The contractor shall bear the cost of any suit which may arise, and shall pay all damages which may be awarded in consequence of the use by said contractor of any patented device in the construction of any work under these specifications.

5.—The contractor shall obtain all necessary permits, and shall assume all risk of accidents to men or materials prior to the acceptance of the finished structure.

Overhead Construction for Electric Traction.

The adoption of electric traction, under the operating conditions prevailing on the present steam roads, introduces a demand for a more substantial type of construction than was necessary for the so-called trolley lines.

Short spans with many supporting poles near the tracks are objectionable in appearance, are a menace to train hands, and are likely to be injured by derailments. With four or more tracks, at standard spacing, poles between tracks will rarely be permitted in the United States, though such an arrangement has been used abroad. Similarly, the superstructures must be self-supporting, or be free from guys parallel to the track. Guys at right angles to the track may be permitted in some localities, but may not be allowable in others, on account of a limited right of way.

Assuming, for present purposes, that men must be permitted to stand on the tops of cars, and that overhead clearance must be given for wrecking cranes and at public crossings, the following clearances must be maintained:

Minimum clear headroom from top of rail to trolley wire									.22	ft.	0 in.
"	"	"	"	"	"	"	"	power "	.22	"	0 "
Minimum clearance from center line of main track									9	"	6 "
"	"	"	"	yard running track					8	"	6 "
"	"	"	"	yard standing track					8	"	0 "

Superstructures may be divided into three classes:

(1)—Two posts or bents supporting a transverse span wire;
(2)—Two posts or bents supporting a transverse truss;
(3)—Single post or bents supporting cantilever brackets.

Of these, the first has been used on various interurban roads, while the recent New York, New Haven and Hartford Railroad installation is the most prominent illustration of the second. The third, which is a heavy type of the present trolley line construction, has not been used in the United States, though it is now in use in Germany, Switzerland and Italy, under more favorable operating conditions than generally obtain on steam roads in America.

Comparing Classes 2 and 3, the former has the following advantages: It has greater rigidity and strength, is better adapted to the erection of catenaries, and permits the telegraph and telephone cables to be widely separated from the power wires. On the other hand, Class 3 offers less obstruction along the tracks, with decreased probability of injury from derailment; less interference with stations, platforms, etc., and permits the addition of tracks without alteration of existing construction.

While two-track bridges can be made comparatively shallow, the depth necessary for four tracks becomes great enough to be an obstruction to the view of upright signals, and the foreground of intermediate trusses will obscure the engineer's view at approximately 1 200 ft.

Catenaries, or the supporting spans for the conductor, are of two general classes: "single," having one messenger cable, with or without an intermediate or "secondary" cable; and "double," in which the conductor is hung by triangular hangers from a pair of messengers. The former type is merely the interurban trolley construction on a larger scale, while the advocates of the latter consider greater rigidity desirable. Up to the present time, these two types have not been suf-

ficiently tested by operation under severe conditions to make possible a definite decision in favor of either. Subject to the successful operation of the trolley pole or pantagraph frame, in connection with the more flexible single catenary, the writer believes the single catenary to be the better type. The single catenary presents a better appearance, offers less obstruction to the view of signals, and costs less, both in original cost and maintenance. It will be found advisable to avoid

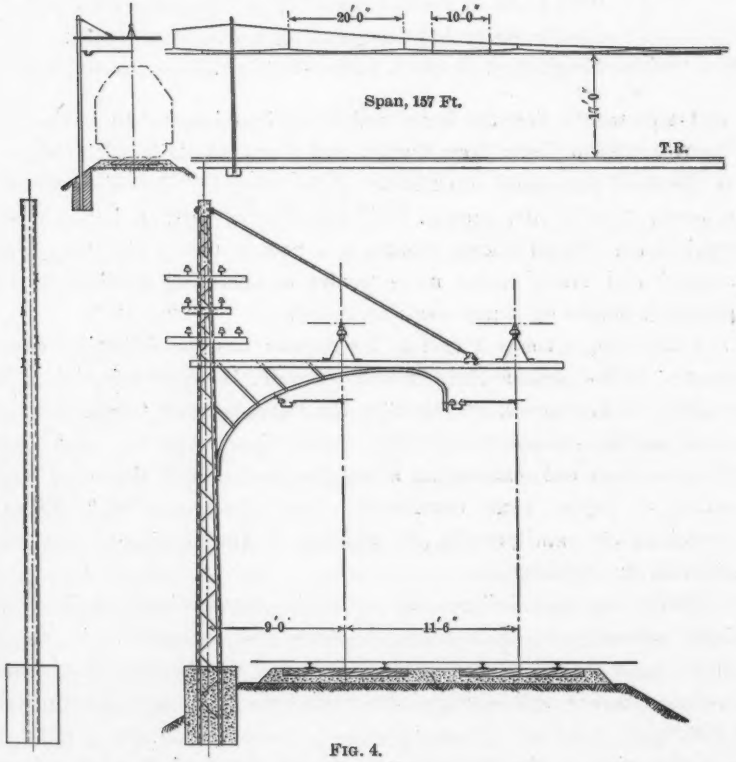


FIG. 4.

many small parts, particularly those of thin section, in catenary construction, inasmuch as, while the need of maintenance should be small, the cost will be relatively high. Work on the ground can be done much more cheaply and easily than that necessitating a work train with telescoping platforms and a right to use the track.

Fig. 4 shows the construction used on several foreign roads.

Catenaries.—The catenary construction is composed of a main messenger cable, from which is hung a secondary messenger, from which in turn the trolley wire is suspended. The main messenger consists of a single catenary about $\frac{3}{8}$ in. in diameter, of 7-strand, high-tension steel, the normal stress being about 1 100 lb., with an ultimate strength of 11 000 lb., or about 140 000 lb. per sq. in. The secondary messenger is a solid steel wire having a diameter of about 0.236 in., a normal tension of about 220 lb., an ultimate strength of 6 200 lb., or about 140 000 lb. per sq. in. The trolley wire is grooved, hard-drawn copper, having an area of about 0.155 sq. in. (approximately No. 0000 trolley wire), with an ultimate strength of 8 800 lb., and maintained at a normal tension of about 1 100 lb. by counterweights at intervals of about 1 mile.

The hangers attaching the trolley wire to the secondary messenger are about 6 in. long, and are looped over the messenger, but not fastened to it. There is an allowance of 2 or 3 in. in the loop, so that the trolley wire and hanger can rise vertically, for 2 or 3 in., without raising the messenger. The hanger itself is rigid, and grips the groove in the trolley wire. Counterweights, maintaining constant normal tension in the trolley wire, are spaced at intervals of about 1 mile, at which points the trolley wires lap past each other at an anchor span, each wire passing around pulleys and being attached to counterweights at the post. This arrangement is also used as a combination section-break.

Catenaries are zigzag to the center line of the track, with a displacement of about $\frac{1}{2}$ m. per span between the ends. Care is taken to erect catenaries with the center of the span on the center line of the track, in order to prevent the trolley wire from approaching too close to the ends of the pantagraph bow.

Turnouts are of simple design, having no additional contact wires (gridiron). Turnout catenary and trolley wires are independent spans, and are pulled over into position adjoining the main span. Pull-off posts are used at curves, and the main spans are not reduced on account of curvature. Steady strains are placed at each post, and have an adjustable connection to the short hanger between the secondary messenger and the trolley wire.

The support for the main messenger insulators is of light construction, and is not designed to resist an unbalanced pull. This construction will be made stronger in future work.

The advantage claimed for a catenary of this type, apart from the reduced cost, is extreme flexibility. The counterweighted trolley wire is maintained at constant tension, while being free to move vertically, and therefore presents fewer hard spots against the pressure of the trolley. If the trolley wire tension and the pressure from the bow are carefully adjusted, the wire might be said to hang from the bow and be free to move up and down, within limits, while being supported locally by the passing shoe.

Superstructure.—The superstructure consists of two-track cantilever brackets having a guy from the outer end of the bracket to the top of the post. The posts also carry seven power wires, and are composed of two channels with flanges turned inward, with single lacing between the webs of the channels. The cantilever bracket is a horizontal arm with a long curved knee-brace, light channels being used for both members. The post channels are embedded in the concrete foundation. The entire construction is very light, and is not capable of resisting unbalanced loads or broken wires without distortion and without depending on adjoining wires exerting a supporting reaction.

Dimensions.—

Main span	157 ft. 0 in.
Distance of trolley wire from top of rail	17 " 0 "
Distance from center to center of tracks	11 " 6 "
Distance from center of track to center of post	9 " 0 "
Intermediate span of secondary messenger (space between hangers)	20 " 0 "
Distance between trolley wire hangers	10 " 0 "
Operation.—Pressure of bow	12 lb.
Voltage	6 600

Two trolleys are used on each motor car, and, as the overhead construction is very flexible, the bow maintains contact at all times, although it can, and does, deflect the trolley wire vertically. No trouble has been experienced in running past turnouts at a speed of 60 miles per hour, and it is confidently expected that there will be no trouble at higher speeds. The contact shoe lasts for about 4 000 miles.

On the Midland Railway, England, and on other foreign roads, a type of construction similar to the foregoing, but with the following modifications, is about to be installed:

Length of span..... 100 m.
Sag ..... 3 m.
Main messenger—7-strand, high-tension steel; 65 sq. mm.; ultimate strength, 100 kg. per sq. mm. (0.1007 sq. in., or 140 000 lb. per sq. in.).
Secondary messenger—solid steel wire; 6½ mm. in diameter; ultimate strength, 100 kg. per sq. mm. (0.0514 sq. in., or 140 000 lb. per sq. in.).

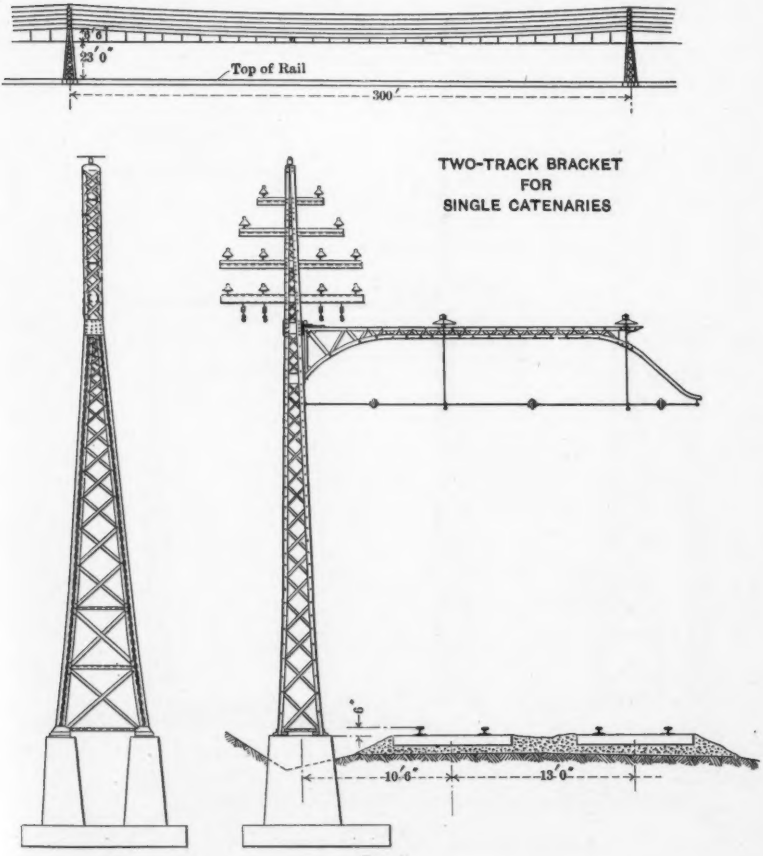


FIG. 5.

Superstructures are to be preferably of the bridge type, instead of cantilever brackets, the overhead "trusses" being light beams (probably channel construction) with supporting guys to the top of the

A-frame posts, and with intermediate posts between the tracks where a number of additional tracks are spanned.

The main catenary insulator supports will be strengthened, and the construction will consist of an insulator supported by the "truss," with

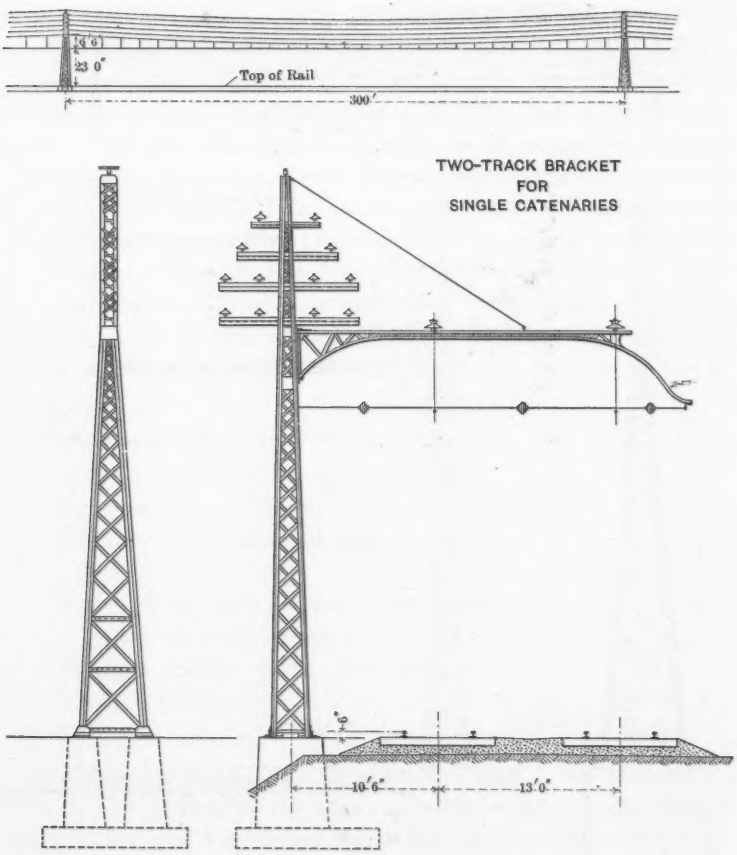


FIG. 6.

a gooseneck carrying another insulator projecting on each side. The main messenger wire will be dead-ended on the insulators at the outer end of the gooseneck.

The writer suggests the types of construction shown in Figs. 5, 6, 7 and 8. As will be noted, these designs are arranged to carry heavy power, telegraph and telephone lines, and may be of two types:

(1).—Cantilever brackets at intermediate points, with anchor and signal bridges spaced about 3 000 ft. apart.

(2).—Bridges for both intermediate and anchor supports.

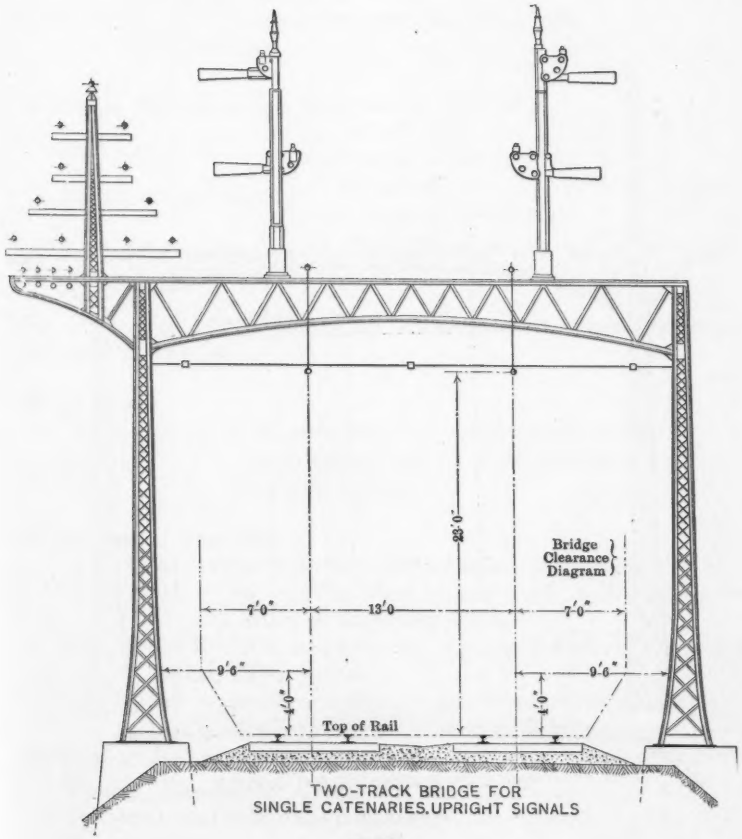


FIG. 7.

General Data.

Spans of 300 ft.,
Single catenaries,
Signal and anchor bridges spaced 3 000 ft. apart,
Power wires (250 000 cm.), stranded copper,
Two 40-pair telephone cables,
Two 25-wire telegraph cables,
No. 0000 trolley wire,
Voltage, 11 000.

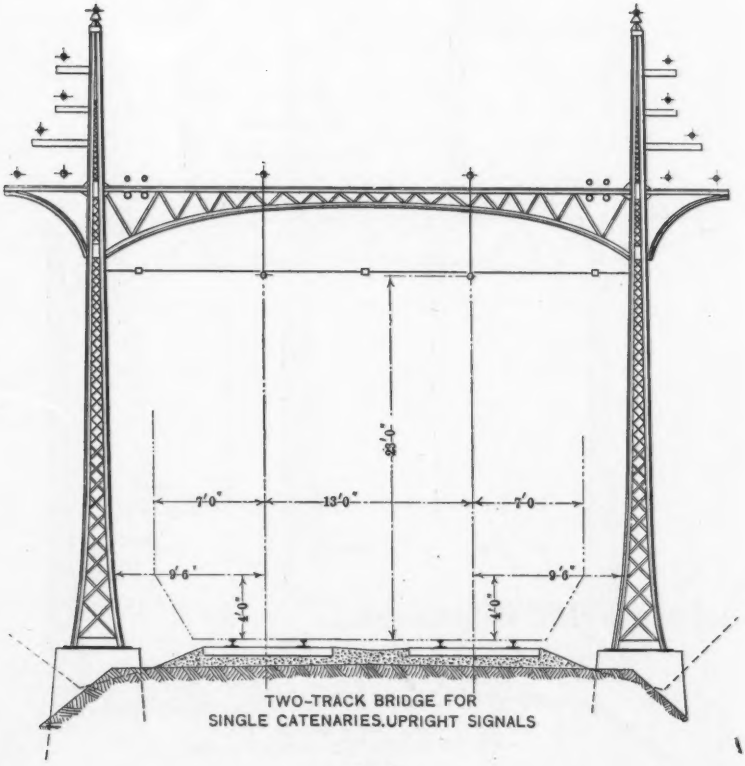


Fig. 8.

Clearances.—

Minimum clearance, top of rail to trolley wire	22 ft. 0 in.
" " " " " " power wires	22 " 0 "
" " " " " " telegraph or telephone cables	22 " 0 "
(except at overhead street bridges, etc.)	
Minimum spacing, center to center of power wires	2 " 6 "
Minimum uninsulated clearance between wires and superstructure	1 " 3 "
Minimum side clearance between insulators and superstructure	0 " 8 "

Minimum Side Clearance from Center of Track.—

Main-line track	at top of rail	9 ft. 0 in.
	4 ft. or more above rail	9 " 6 "
Yard running track	at top of rail	8 " 0 "
	4 ft. or more above rail	8 " 6 "
Yard standing track	at top of rail	7 " 6 "
	4 ft. or more above rail	8 " 0 "

Ice Load.—Ice $\frac{1}{2}$ in. thick all around exposed members; weight of ice 0.033 lb. per cu. in.

Wind Load.—

8.0 lb. per sq. ft. of projected area of ice-covered wires.
12.0 " " " " of projected area of wires without ice.
20.0 " " " " on flat surfaces.

Conditions of Loading.—

(1).—Dead + ice + 8 lb. wind on adjoining spans.
(2).—Dead + ice + 8 lb. wind on one span; and dead + ice + 2 lb. wind on adjoining spans.
(3).—Dead + 12 lb. wind on one span, and dead + 4 lb. wind on adjoining spans.
(4).—Dead + ice on one span, and dead on adjoining spans.

Factors of Safety.—

Trolley messengers	3
Telegraph and telephone messengers	2
Power wires	$2\frac{1}{2}$
Ground wires	$2\frac{1}{2}$
Steel superstructure	$2\frac{2}{3}$
Insulator pins	3

Ground Wire.—A suitable galvanized, stranded steel wire shall be suspended parallel to and over the group of power wires. The ground wire need not be at the apex of a 60° angle enclosing all the wires.

Thickness of Material.—The metal in all steel superstructure shall be not less than ¼ in. in thickness.

Temperature.—Provision is to be made in the determination of stresses and clearances, and in erection, for a change in temperature of 70° fahr. above and 80° fahr. below a normal temperature of 60° fahr.

Bolts.—Bolts are not to be used in place of rivets, except as specified, and when used the holes are to be reamed and the bolts made to a close fit.

Galvanizing.—Messenger wires, guy wires, clamps, insulator pins, etc., are to be galvanized in an approved manner.

Unit Stresses.—

Tension	22 500	lb. per sq. in.
Compression	22 500	lb.—82 $\frac{l}{r}$
Shear: Shops rivets and pins	12 000	lb. per sq. in.
Field rivets and bolts	9 000	" " " "
Bearing: Shop rivets and pins	24 000	" " " "
Field rivets and bolts	18 000	" " " "
Bending: Pins	24 000	" " " "
Bearing on concrete foundation	350	" " " "

Design.—If necessary to an economical design, it would be logical to assume higher unit stresses to apply to the case of broken wires, such incidents being presumably of very rare occurrence. It seems to be unreasonable to design the entire line with the normal factor of safety for a condition that will certainly never occur on the whole line, and may never occur on any of it.

It is assumed that the trolley messenger cables, having a factor of safety of 3 under maximum loading, will not break except when burned, and that such burning will not occur under ice and wind load. The result of such an accident would be to rotate the brackets, break some insulator clamps, and probably stop traffic on one 3 000-ft. section, but not to cause failure of the steel superstructure.

The connection of telephone and telegraph cable messengers should be made by swinging hangers, which will allow alterations of adjoining span lengths, and thereby balance unequal tensions in adjoining spans.

Cantilever brackets supporting catenaries should be designed with pivoted or pin-ended connections in order to permit a horizontal motion of the brackets, and balance any unequal tension in the adjoining catenary spans.

The condition of unequal loading on adjoining spans, due to localized ice or wind loading, does not appear to have been considered by all designers. The conditions of loading given in the specifications, which include a reasonable unbalanced loading, will certainly occur, and should be considered. By a careful arrangement of outline, swinging connections for telephone and telegraph cables, and a small amount of post deflection, the effect of this unbalanced loading on the steelwork may be reduced to approximately the same amount as that of ice and wind on two adjoining spans, which condition of loading is generally accepted.

Superstructures.—The form of the steel supports will depend on local conditions and the line requirements, and may properly be bridges, cantilever brackets, or span wire construction, and may be either built sections or pipe construction.

Foundations.—All foundations should be of concrete.

Trolley Catenaries.—Catenaries, namely, the self-supporting spans of trolley wire, or the supporting spans for a non-self-supporting trolley wire, are of three general classes:

(1).—"Simple catenary," or span of trolley wire;

(2).—"Single catenary," having one supporting messenger cable, with or without an intermediate or secondary messenger;

(3).—"Double catenary," in which the trolley wire is hung by triangular hangers from a pair of messengers.

Simple catenaries, of the type now in use on the various trolley roads, are only available for short spans, because the copper trolley wire cannot withstand the stresses of long spans with small sag. By a modification of the ordinary hanger, Joseph Mayer, M. Am. Soc. C. E., has designed a type of simple catenary which, it is claimed, reduces the stresses in the wire to allowable units.

Simple catenaries and single catenaries, unless provided with lateral guys, are subject to criticism on the score of lateral displacement from wind pressure. Such displacement, in amount sufficient to carry the

trolley wire beyond the range of the contact bow, can only occur locally during severe wind storms. If, however, a locomotive should be in a given span during such displacement, the contact bow would probably rise above the wire and, catching above it, be torn off.

Double catenaries seem to the writer to be less desirable than the foregoing types, for the following reasons:

(1).—Greater first cost of catenaries, insulators, and supporting steelwork;

(2).—More members to maintain, and these of a construction more difficult to maintain;

(3).—Greater mass of material above the tracks, with more unsightly appearance;

(4).—More obstruction to the view of signals, and to the location of signal posts;

(5).—The greater rigidity of the trolley wire does not seem to be a point in favor of double catenaries, but, on the contrary, to cause sparking at the contact bow.

Assuming, then, that either "simple" or "single" catenaries are desirable, it becomes necessary to determine which one of the following types is best suited to meet the conditions of first-class traffic:

(1).—Simple catenary (Mayer's saddle suspension);

(2).—Single catenary;

(3).—Single catenary with secondary messenger (German method).

The writer does not consider that, as yet, a definite decision can be made in favor of any one type, particularly as the result of experience under actual operating conditions is the only satisfactory proof. It is not necessary to obtain some saving in first cost, which must be relatively slight, but it is very important to obtain a construction fulfilling certain requirements.

The maximum stresses in catenary or trolley wire produced by ice and wind loads, temperature changes, or the pressure of the contact bow at high speeds, should not exceed a safe percentage of the elastic limit of the material. There should be sufficient lateral and vertical rigidity to prevent undue displacement from the pressure of the contact bow. The weight, sag, and factor of safety may be chosen so as

to reduce somewhat the likelihood of lateral displacement from wind pressure, otherwise the relative importance of providing lateral rigidity is to be considered.

The trolley wire should have some flexibility, in order to maintain contact with the collector shoe, unless, as seems improbable, a support for the collector shoe can be devised which will adjust itself to all inequalities in the trolley wire. It will be necessary to eliminate, as far as possible, the formation of "hard spots" in the trolley wire, due to the hangers. Local bends may be the cause of sparking, whether they are formed during erection, or by displacement, or by the contact pressure. Simple details, readily replaced, and avoiding the use of thin metal sections, will materially reduce the cost of maintenance.

A successful type of catenary should be adapted to changes in elevation caused by overhead street bridges, without introducing marked differences in the action of the contact bow against the trolley wire.

Pantagraph, or Supporting Frame for the Collector.—There is a very close relationship between the characteristics of a trolley wire and those necessary in a pantagraph frame which will work successfully on that wire.

The use of two pantagraphs, or two collectors, per locomotive will materially reduce trouble from sparking, simultaneous jumping of both contacts being improbable.

The ideal type of pantagraph or supporting frame would be one having rigidity against lateral and longitudinal wind pressure, simplicity of construction, flexibility, little mass or equivalent weight pressing against the trolley wire, and at the same time the ability to maintain contact.

Aside from the sparking at the contact, the possible wear on the trolley wire and on the pantagraph frame, a successful design should keep the wear on the contact shoe within reasonable limits.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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A NEW SUSPENSION FOR THE CONTACT WIRES OF ELECTRIC RAILWAYS USING SLIDING BOWS.

By Joseph Mayer, M. Am. Soc. C. E.
To be Presented February 5th, 1908.

For high speeds and the high voltages generally used with them, the ordinary trolley wire suspension has proved unsatisfactory. Single or double catenary suspensions, therefore, have largely taken its place. They permit the use of longer spans, and thereby diminish the number of poles, brackets, and insulators.

With single catenary suspensions, spans of 120 to 150 ft. are mostly used. In these the contact wire is suspended at short intervals from a galvanized steel strand above, and is approximately straight and of the same length at all temperatures. Cold weather, therefore, greatly increases its tension. The amount of increase depends on the modulus of elasticity and the coefficient of expansion of the wire.

The modulus of elasticity of copper wire varies considerably. For very hard wires, it is given as high as 20 000 000 lb. per sq. in.; for moderately hard wire, such as is commonly used for contact lines, Mr. Blackwell gives 16 000 000 lb. as a fair average. The coefficient of expansion for changes of temperature is $\frac{1}{104\,400}$ per degree Fahren-

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

heit. The change in tension per square inch, per degree Fahrenheit, in a wire of constant length, therefore, is 191.5 lb. in the former, and 153.2 lb. in the latter case.

For 140° variation of temperature, the change in tension per square inch is 26 810 lb. in the former, and 21 450 lb. in the latter case. To avoid this variation in the tension of the contact wire, an automatic adjustment of its length has been adopted on the line, Blankenese-Ohlsdorf, near Hamburg, Germany, recently opened for traffic.

If the contact wire is firmly held by rigid suspenders without hinges, the sliding bow which rises between succeeding suspenders bends the wire in a rather sharp curve as it approaches them. At the suspenders this curve is convex downward. To prevent the jumping of the sliding bow at these curves, it must be very light, and the wire must be under high tension. At a speed of 75 miles per hour the sliding bow, with suspenders 10 ft. apart, must make eleven complete up-and-down oscillations per second. With such rapid oscillations, even if they are of very small amplitude, it is very difficult to prevent jumping and sparking; it is impossible, without springs between the bow and its heavy supporting frame, unless the bow itself is a spring.

The bending strains in the wire at the suspenders are also objectionable. To avoid large deflection of the contact wire by the pressure of the sliding bow, its minimum tension in summer must be considerable. The tension in winter is then very large. To this must be added the bending strains arising from the deformations caused by wind pressure, changes of temperature and the pressure of the sliding bow. At high speed the latter is very variable because the bow oscillates rapidly. The consequent bending strains in the contact wire are greatly reduced, in the Blankenese-Ohlsdorf line, by the use of a supplementary steel wire some distance above and parallel with the copper contact wire. The contact wire is hung by loops 3 m. apart from this steel wire, and can rise at these loops, thus permitting the wave raised by the sliding bow to pass unhindered.

The supplementary wire, which, like the contact wire, is nearly horizontal at all temperatures, is carried by suspenders, at intervals of 6 m., from a steel strand above having considerable deflection. The contact wire is grooved, and 100 sq. mm. in cross-section, the steel wire is 6 mm. in diameter, and the steel strand above is of seven

wires, having a total cross-section of 350 mm. With a small contact pressure, the lifting of the wire by cross winds and the passing sliding bow may not be sufficient to permit the latter to touch the supplementary wire and the suspenders. The whole design is ingenious, but complicated and expensive to install, and probably troublesome to maintain. It shows a clear appreciation, resulting from past experience, of the main defects of the catenary suspensions, namely, the excessive tension in the contact wire in winter, the large bending strains in the wire at the suspenders produced by the sliding bow, and the jumping of the latter.

The details of the automatic adjustment of the tension of the contact wire by counterweights are complicated, due to the necessity of insulation, and the impossibility of running the wire over pulleys of moderate size without excessive bending strains. The writer is not aware that such details have been published. The spans of the carrying strand are 48 m., and steady braces are used at the brackets to prevent any lateral deflection of the contact wire there. Large bending strains in the contact wire, at these points and probably at the automatic adjustment of its length, due to lateral deflection by wind pressure, are inevitable. That such complicated and expensive contrivances have been adopted, in the country having the longest experience with catenary suspensions, proves that the much simpler structures previously in use have not been satisfactory even with the moderate speeds used thus far. This is also confirmed by the recent adoption of very short spans without ropes, but with two wires per phase, tied together at short intervals, for the approaches of the Simplon Tunnel.

Since the adoption of steel strands for carrying the contact wire leads to such complicated contrivances, it is worth while to search for a simpler solution of the problem. A clear statement of it will be helpful for the purpose.

The contact wire serves as the track for a rapidly moving sliding bow. It cannot be straight because it must pass at an elevation of about 16 ft. under overhead crossings and at an elevation of about 24 ft. over grade crossings. The horizontal curvature gives no trouble in this respect, as long as the wire does not pass beyond the range of a sliding bow of moderate length. The sliding bow, however, must follow the vertical curvature of the wire. This results in centrifugal

force and consequent variation of the contact pressure. The amount of centrifugal force is proportional to the square of the train speed and to the weights of the parts of the sliding bow and its supporting frame moving in curves, and inversely proportional to the radii of curvature of their motion. Where the curvature of the motion of the sliding bow is convex upward, the contact pressure is increased; where it is convex downward, it is reduced. The increase, if acting on the wire, should not be large enough to produce dangerous bending strains, and the reduction should not produce interruption of contact and consequent sparking.

The contact wire is exposed to tensions and bending strains, produced by weights, wind pressures, pressure of the sliding bow, and changes of temperature. The sum of these should never, and nowhere, exceed a safe limit. These ends should be attained by the simplest possible means. Simplicity demands the use of long spans, and these require large deflections in the contact wire for preventing excessive tensions. With large vertical deflections, strong winds produce large horizontal deflections. The length of the practicable sliding bow fixes the permissible horizontal deflection. Large and round wires are deflected less by wind than small and grooved wires. The permissible vertical deflection, therefore, is influenced by the practicable length of the sliding bow and the shape and size of the wire. Drop of temperature shortens the wire, reduces its deflection, and increases its tension; it thereby reduces the safe span.

An adjustment which will lengthen the wire in winter will evidently permit the safe use of longer spans. Large deflections result in steep terminal slopes of the contact wire, and a large variation of this slope is produced by changes of temperature and by the lifting of the wire by the passing sliding bows. The large lateral deflections produce large lateral slopes of the wire at the clamps. If the wire leaves the clamps in a fixed direction it will be bent up and down by changes of temperature and the passing sliding bows, and to the right and left by cross winds. This bending of the wire at the ends of the clamps results in bending strains which are large in long spans and are the principal reason why such spans are impracticable with ordinary clamps.

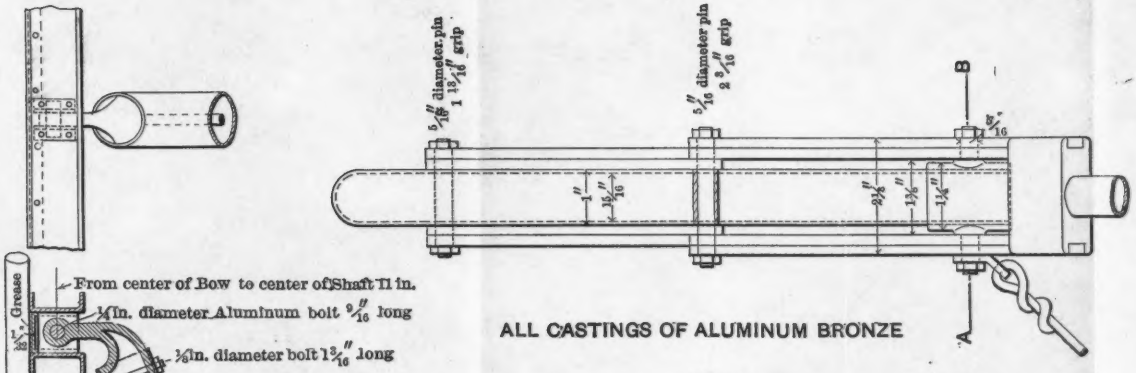
If long spans are to be used with safety, these strains must be reduced. Due to the variable vertical terminal slope of the wire, the

sliding bow approaches the clamp with a variable upward slope of its motion. It should pass the clamp along a curve of large radius tangent to this variable slope of approach. This is not practicable if the wire leaves the clamp in a fixed direction.

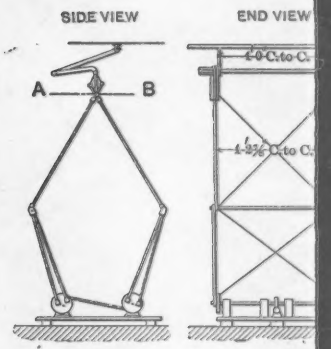
The reduction of the bending strains in the contact wire at the clamps and the creation of a smooth track, of large curvature, at all temperatures, for the sliding bow is obtained by the suspender shown on Plate CXI. It consists of four castings firmly bolted together and provided with a central ear for attaching it to an insulator pin. The wire is firmly held in the central part of the suspender. It leaves this central part 8 in. long with vertical slopes of 3% below the horizontal. The suspender is designed for 240-ft. spans of 000 B. & S. gauge wire, with 2½ ft. maximum vertical deflection. It is intended for use on a line having maximum train speeds not exceeding 80 miles per hour.

The variation of temperature is assumed at 140° fahr. Strain adjusters, one mile apart (to be described later) in effect reduce this variation to 84° fahr. The central part of the suspender encloses the wire. The sliding bow moves here, along the bottom of the suspender, along an arc of a circle having a radius of 11 ft. 1½ in. Where the wire leaves the central part, its bottom is tangent to the bottom of the suspender. Next to the central part of the suspender are two channels, open below. These channels have top walls which, in effect, are horizontal cylinders of 75 ft. radius. The top walls are tangent to the top of the wire where it leaves the central part. The walls are recessed, for easier manufacture. The side walls, which are only 14 in. long, are vertical cylinders of 70 ft. radius. They are tangent to the sides of the wire where it leaves the central part. Below these terminal channels of the suspender the sliding bow moves along the bottom of the wire. The lower edge of the side walls, for all positions of the wire, is above its bottom, so that the side walls will not interfere with the sliding bow. On curves, the suspender is hung with its bottom parallel to the plane of the track.

The wire is assumed to have an ultimate strength of 50 000 to 60 000 lb. per sq. in. and an elastic limit of 40 000 to 45 000 lb. The modulus of elasticity is assumed at 16 000 000 lb. With these assumptions, the largest tension in the wire is 20 850 lb. per sq. in. The largest bending strain at the same time is 5 340 lb. This gives a total

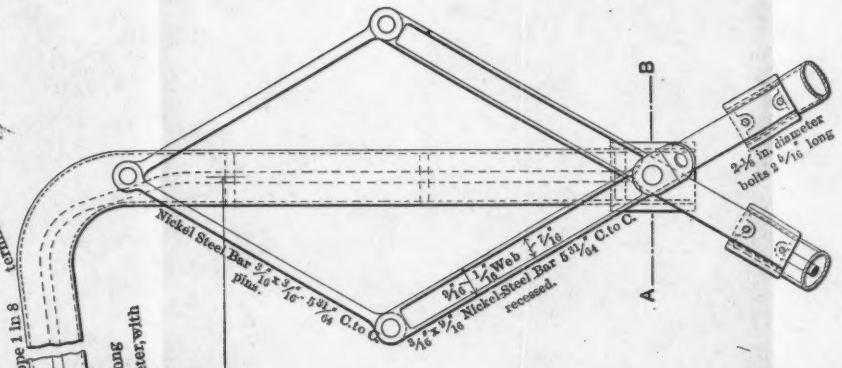


ALL CASTINGS OF ALUMINUM BRONZE

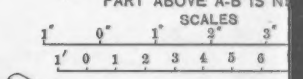


Extreme positions of
Bow Pin 14.7 in., and 3 in. above hinge.
Range of Vertical motion of bow
relative to hinge 11.7 in.

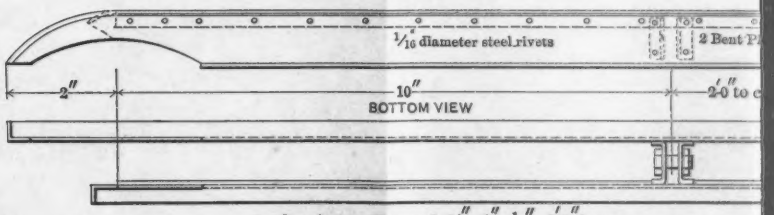
This Bow is suitable for the Saddle Suspension for train speeds up to 50 miles per hour, without strain adjusters, and for 75 miles per hour with strain adjusters,
Equivalent Weight of Bow and radial arms 3.0 lb.



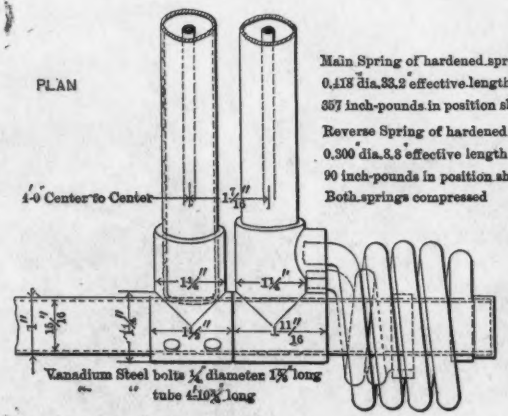
HIGH-SPEED SLIDING
VERTICAL RANGE OF MOTIO
PART ABOVE A-B IS NE
SCALES



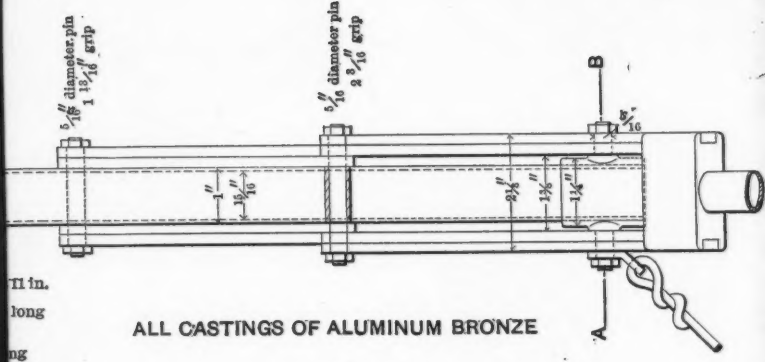
ALUMINUM SLIDING BOW



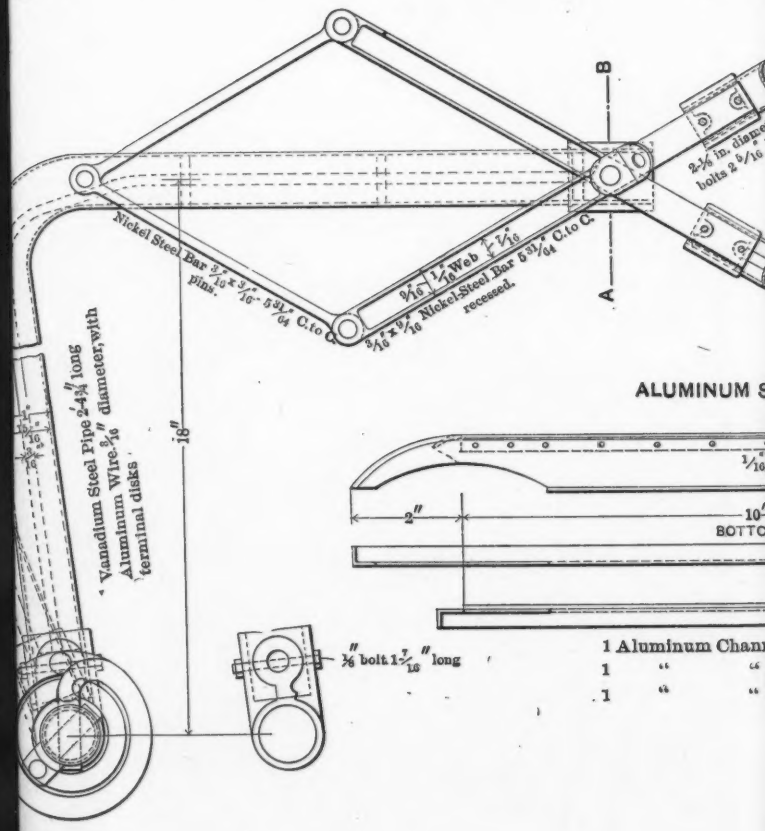
1 Aluminum Channel ⅜" x 1" x 1/16" - 6-0" long
1 " " " - 5-0" "
1 " " " ¼" x ¾" x 1/32" - 5-8" "



Main Spring of hardened spring steel
0.418" dia. 33.2" effective length; torque
357 inch-pounds in position shown.
Reverse Spring of hardened spring steel
0.300" dia. 8.8" effective length; torque
90 inch-pounds in position shown
Both springs compressed

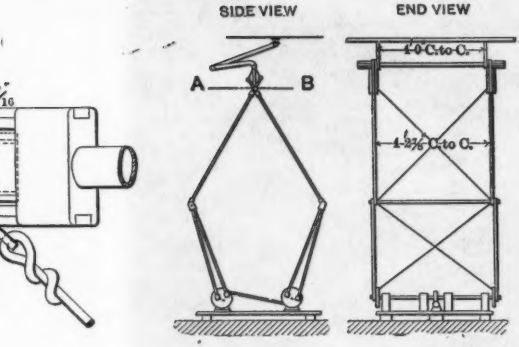


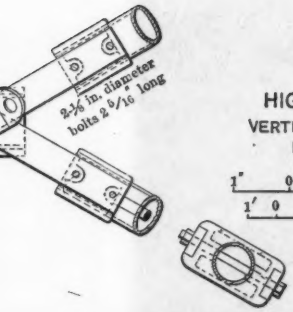
ALL CASTINGS OF ALUMINUM BRONZE



ALUMINUM S

1 Aluminum Chan
1 " "
1 " "

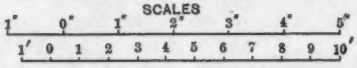




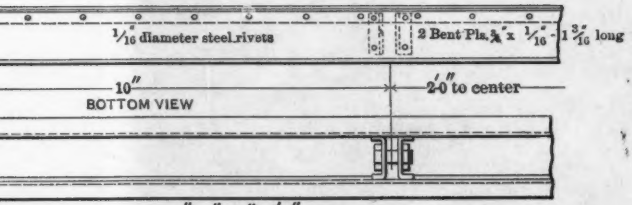
HIGH-SPEED SLIDING BOW

VERTICAL RANGE OF MOTION 8 FT.
PART ABOVE A-B IS NEW

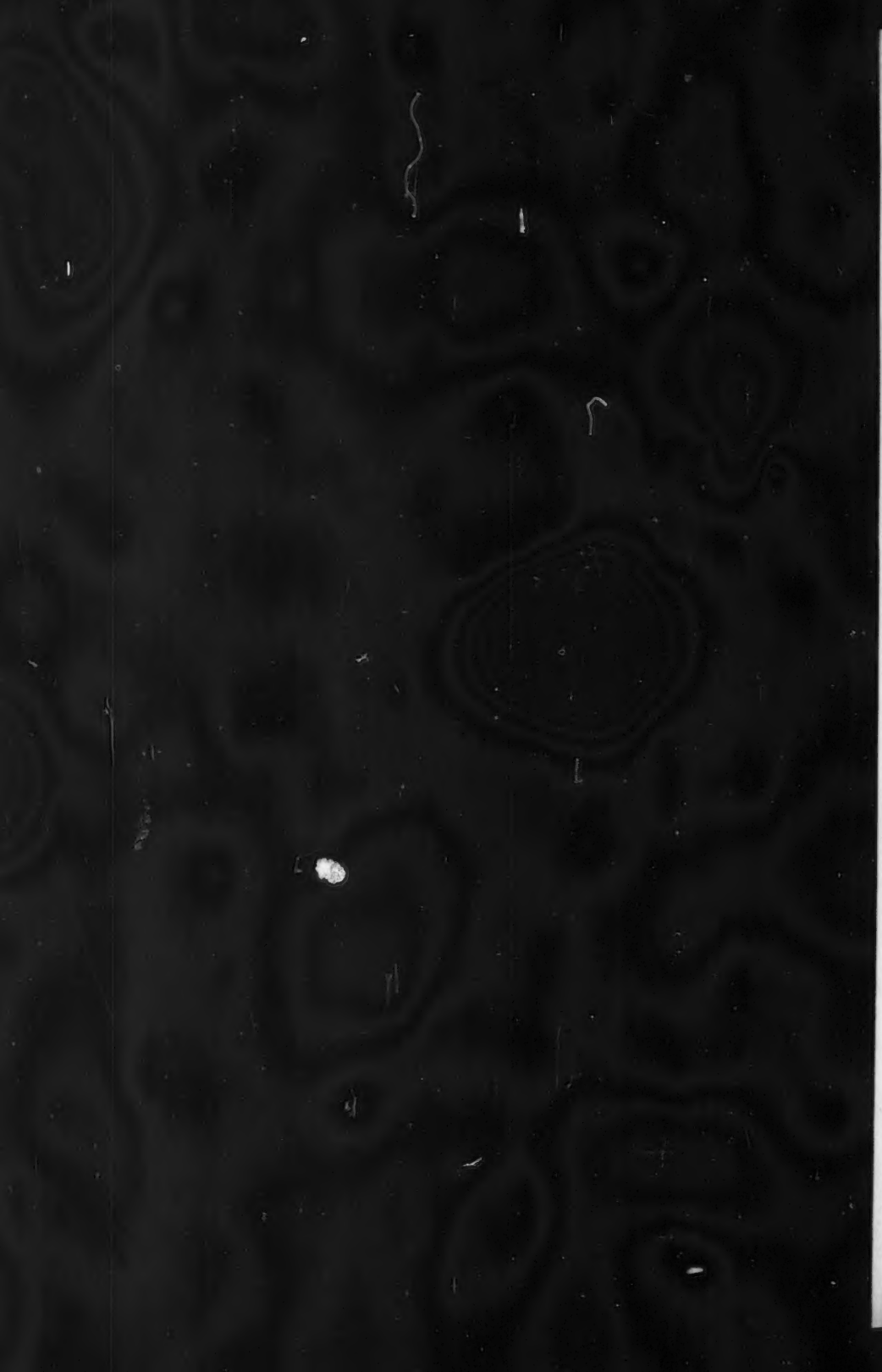
SCALES



ALUMINUM SLIDING BOW



luminum Channel 3/8" x 1" x 1/16" - 6-0" long
" " " " -5-9" "
" " 1/4" x 3/4" x 1/32" - 5-8" "



maximum strain 26 190 lb. No ice was assumed on the contact wire. Ice averaging ¼ in. in thickness, increasing the diameter by ½ in., would increase the tension to 22 450 lb. per sq. in.

These strains give to the contact wire about the degree of safety of first-class railroad bridges. They amount to about as much as the maximum tensions, exclusive of bending strains, in the contact wires of the best catenary suspensions of the United States.

For a speed of 80 miles per hour, the equivalent weight of the sliding bow should not exceed 2½ lb., that is, the sliding bow and its frame should produce no larger centrifugal force than a weight of 2½ lb. moving like the contact point. With a wind pressure of 12 lb. per sq. ft. of wire, counting diameter into length as the area, its largest lateral deflection is 1.8 ft.

To avoid cutting a groove in the sliding bow, the suspenders must be placed alternately to the right and left of the center line of the track. The sliding bow must have an effective length of 4 ft.

The suspender is similar in its action to the saddle carrying a cable of a suspension bridge. It is an inverted saddle, open below, and provided with sides and a roof against which the wire rests when it is deflected upward or to the sides. The term, saddle suspension, therefore, appears to be an appropriate name.

The strain adjuster, shown on Plate CXII, consists essentially of two half suspenders, each cast in two pieces, and carrying cross-heads which are guided by a stout steel bar and moved by steel or bronze screws. The half suspenders change the direction of motion of the sliding bow to a horizontal one. Two properly shaped plates form the track for the sliding bow between the two half suspenders. The whole is attached to a suitable frame, and is carried by insulators from a bridge crossing the tracks. The distance between the two half suspenders can be varied about 2 ft. 8 in. by turning the screws. The brackets carrying the other suspenders must be hinged at the posts, so as to permit free motion of the suspenders within a limited range, approximately in the direction of the track, without changing the direction of the suspenders. The tension in the contact wire will then automatically readjust the position of the suspenders and the lengths of the spans when the screws of the strain adjusters are turned. The same end can also be easily attained by span wire construction.

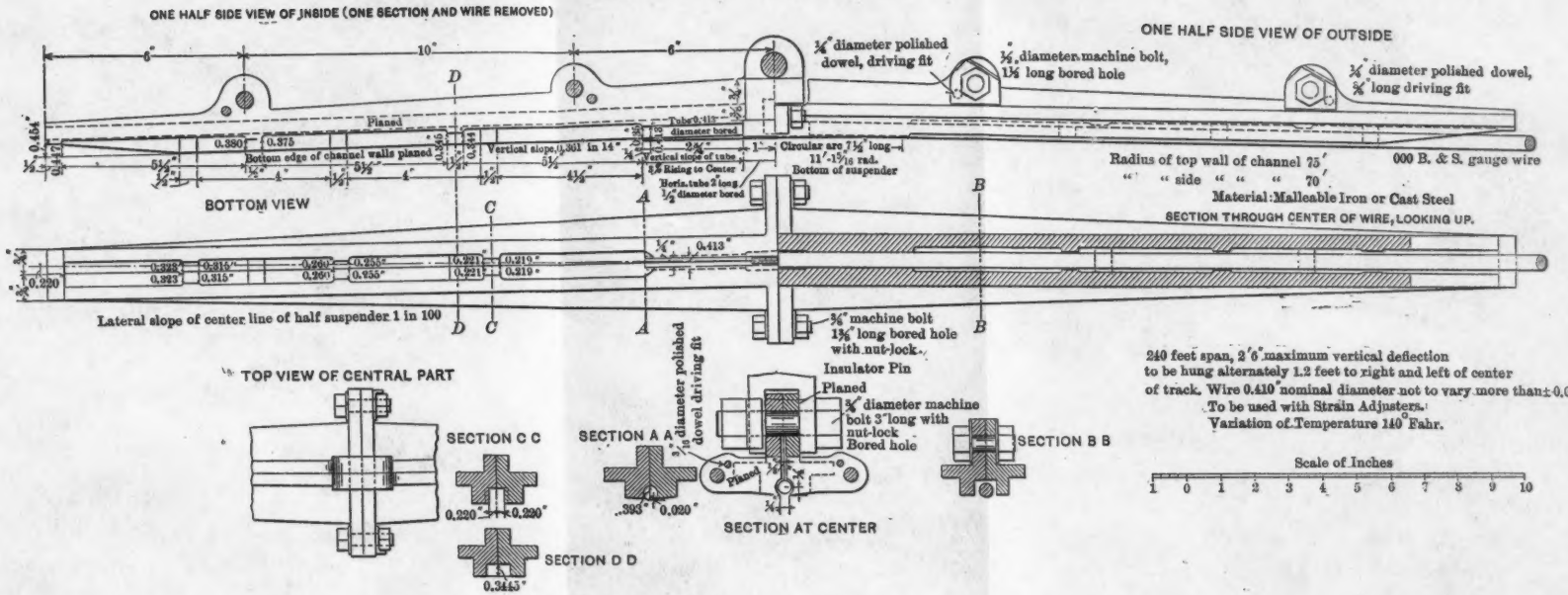
The bridge carrying the strain adjusters and its supporting posts should be of sufficient strength to serve as an anchorage in case the contact wire of an adjoining span is broken by a derailment overturning a post. The swinging brackets or span wires, in this case, will probably prevent the overturning of other posts. The adjustment must take place once or twice in the fall, when the cross-heads are let out, and as often in the spring, when they are pulled together. It will generally be possible to reduce the variation of temperature with one adjustment to 84° fahr. or less. These strain adjusters effect a large reduction of the maximum tension in the contact wire, and thereby make possible the safe use of longer spans with moderate maximum deflections. An automatic adjustment producing constant tension in the contact wire would be desirable, and is attempted in the Blankenese-Ohlsdorf line. It is reported that the contact wire is run over pulleys to the side of the track and attached to counterweights. The wires used are probably grooved, and at least 0.2 in. wide. Running such a wire over a pulley 25 ft. in diameter results in a bending strain of 10 667 lb. per sq. in. This balances the reduction in tension obtained. To gain any advantage, a much larger pulley must be used.

The writer believes that large bending strains in the contact wire cannot be avoided in any adjustment appliance, without using substantially the suspender here described. After a number of futile attempts to find something more perfect and automatic than his strain adjuster, he arrived at the conclusion that a further reduction of the maximum tension in the contact wire cannot be obtained at moderate cost by any sufficiently simple and reliable strain adjuster.

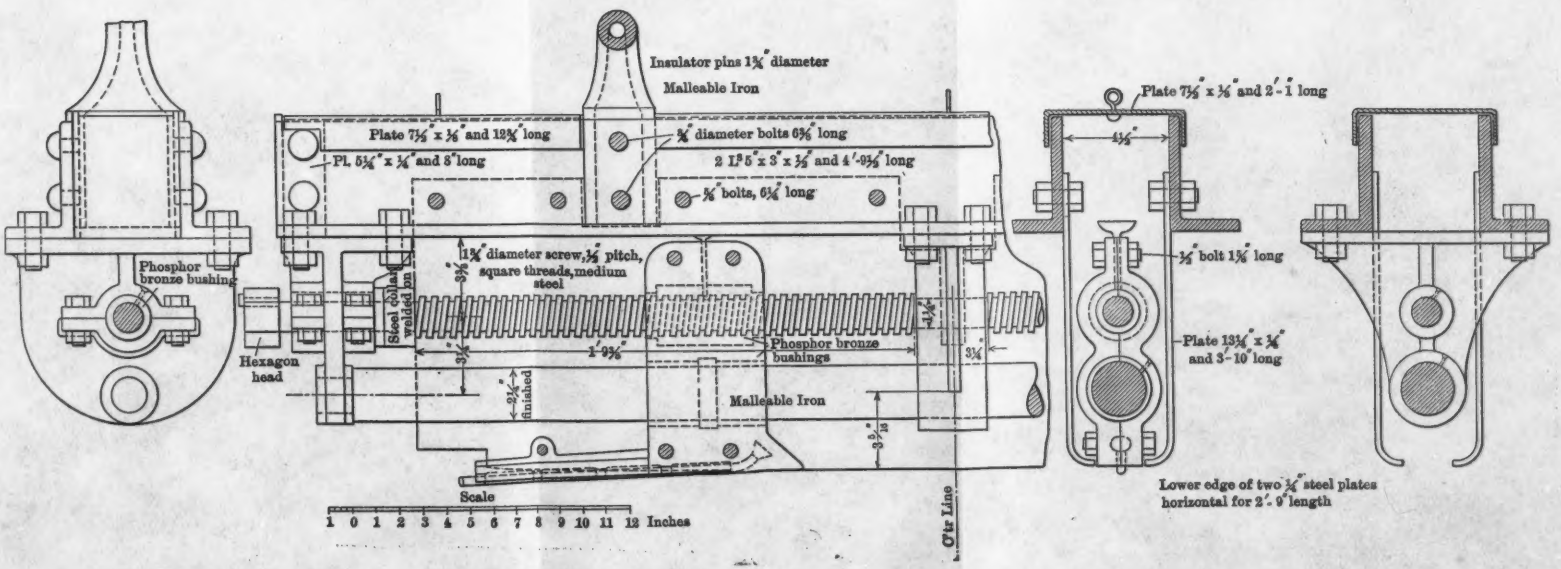
With the catenary constructions, large deflection of the contact wire by the sliding bow must be prevented by the stiffness and tension of the wire. To obtain these safely, a large wire is essential for high speed. With the saddle suspension, 0 B. & S. gauge wire is fully adequate to obtain the requisite mechanical strength, therefore, with it, the size of the wire is mainly governed by the needed electrical conductivity.

On a superficial consideration it would appear that it is more difficult to make a sliding bow that will rise and fall 1 or 2 ft. during the passage of a 240-ft. span than to make one that will rise and fall ½ in. or 1 in. in a span of 10 or 13 ft. The opposite, however, is true.

SUSPENDER FOR 000 B. & S. GAUGE WIRE



STRAIN ADJUSTER FOR CONTACT CONDUCTOR



The sliding bows used with catenary suspensions must be able to follow the wire at overhead and grade crossings; therefore, they must have a range of vertical motion of about 8 ft. Unless the approach slopes to these crossings are made very long, the sliding bows must be able to follow the contact wire around a considerable vertical angle.

With the saddle suspension, the sliding bow must follow a vertical angle in the contact line at every suspender. The necessary ability to do so is used more often with the saddle suspension. The sliding bow described in Appendix C can be used for the highest railway speeds with a properly designed saddle suspension.

The sliding bow for the catenary suspension must also be fit for extremely rapid oscillations of small amplitude. In oscillations of the same amplitude, the maximum velocity of the oscillating body is proportional to the number of oscillations per second, and the maximum acceleration is proportional to the square of this number. The maximum velocity and acceleration are both proportional to the amplitude. The variation of the contact pressure is proportional to the maximum vertical acceleration of the sliding bow. With the same law of oscillation, the same maximum acceleration would be obtained if the amplitude were inversely proportional to the square of the number of oscillations per second. In this case the amplitude of the large and slow oscillations with the saddle suspension and that of the small and rapid oscillations with the catenary suspensions are about inversely proportional to their numbers per second. The laws of the two oscillations are not the same, but it is evident that, with the suspenders here described, the small and rapid oscillations of the catenary suspensions require a larger upward acceleration of the sliding bow, and therefore produce a larger reduction of the contact pressure.

With the catenary suspensions, the calculation of the variation of the contact pressure is extremely complicated, and, the writer believes, has never been accurately performed. With a properly designed saddle suspension, the calculation is simple, the shortest radii of the curvature of the motion of the sliding bow being given in the design of the suspender.

The foregoing gives the results of the writer's investigations, the proofs are given in the appendices.

Reviewing the problem: The aim is a safe contact wire, cheap to

construct and maintain, offering a suitable track for a rapidly moving sliding bow. The wire is safe if exposed to moderate maximum strains not exceeding three-fourths of its elastic limit. To prove its safety, the bending strains and tensions produced by the incident forces and the changes of temperature must be calculated.

Appendix A gives the derivation of approximate formulas for calculating the bending strains produced by normal forces in a wire under tension.

Appendix B calculates the maximum coexisting bending strains and tensions for a particular case of the saddle suspension; it also gives the bending strains and tensions for a suspension with ordinary clamps.

Appendix C gives the theory and description of a sliding bow, suitable, with the highest train speeds, for the saddle suspension. In previous pamphlets, entitled: "Overhead Contact Lines" and "The Saddle Suspension," the writer has described the same problem, and has there compared the different suspensions. His views on several details have since been modified by a study of the action of sliding bows.

APPENDIX A.

In many designs of suspensions, the bending strains in the contact wire far exceed the tensions. Their neglect makes many inferences from calculations of the tension only utterly misleading.

The writer has developed formulas for calculating the bending strains in the contact wire produced by a known pressure of the sliding bow, and those at the ends of the clamps firmly holding the wire in a fixed direction produced by lateral and vertical deflections. For round copper wires having a modulus of elasticity of 16 000 000 lb. per sq. in. the formulas are as follows:

For 0000 B. & S. gauge wire $S = 10\,900 \frac{Q}{\sqrt{T}}$

" 000 " " " " $S = 11\,800 \frac{Q}{\sqrt{T}}$

" 00 " " " " $S = 12\,700 \frac{Q}{\sqrt{T}}$

" 0 " " " " $S = 13\,600 \frac{Q}{\sqrt{T}}$

Q is the pressure of the sliding bow, in pounds;

T is the tension in the wire, in pounds;

S is the bending strain per square inch.

The formulas are approximately correct for the usual values of Q and T.

In a wire held in a clamp and exposed to a tension, T, differing in direction from that of the wire where it issues from the clamp there arises a bending strain largest at the end of the clamp. If the tension, T, is decomposed into a component acting in the direction of the issuing wire and a component, N, normal to it, then the above formulas give the bending strain per square inch for $Q = 2\,N$.

The proof for these formulas for wires with a modulus of 20 000 000 lb. per sq. in. is given in the writer's pamphlet, "Overhead Contact Lines," S is approximately proportional to the square root of the modulus of elasticity.

APPENDIX B.

Calculation of a suspender for a 240-ft. span of 000 wire with 2 ft. 6 in. maximum vertical deflection for a train speed of 80 miles per hour. Variation of temperature 140° fahr., reduced in effect to 84° fahr. by strain adjusters.

By numerous trial calculations, it was found that, with the assumed speed, the design of a suitable sliding bow is difficult with larger deflections. Longer spans give maximum strains in the contact wire which, though much smaller than those in the contact wires of most catenary suspensions, are believed to be inadvisable at the start. A large factor of safety is possible with this suspension without excessive cost and complication, therefore, it has been the governing consideration in selecting the design.

With a deflection of 2 ft. 6 in., the vertical terminal slope of the wire is 4.17 per cent. A train running at 80 miles per hour will have generally two sliding bows; these lift the wire and approach the suspender at a much flatter slope. The weight carried by the wire to the suspender is reduced by the two approaching bows by an amount depending on their contact pressure and distance apart. With a contact pressure of 15 lb., which is needed for preventing jumping at the suspenders, and 30 ft. distance of the two sliding bows, the weight carried by the wire to the suspender is decreased, at the arrival of the first bow, from 60.8 lb., the weight of a half span of wire, to 32.7 lb. The slope of approach of the sliding bow is reduced in the same ratio, or to $4.17 \times \frac{32.7}{60.8} = 2.24$ per cent. The vertical component of the velocity of the sliding bow at 80 miles per hour is then $117.33 \times 0.0224 = 2.63$ ft. If there is occasionally only one sliding bow, this upward velocity of approach to the suspender is:

$$4.17\% \times \frac{45.8}{60.8} \times 117.33 = 3.14\% \times 117.33 = 3.678 \text{ ft.}$$

As shown in Appendix C, this can be easily taken care of by the sliding bow there described.

The length of one span of the contact wire is given by the formula:

$$S = L + \frac{8}{3}\frac{D^2}{L} = 240 + \frac{8 \times 2.50^2}{3 \times 240} = 240.0694 \text{ ft.}$$

The tension due to the weight of the wire is:

$$T = \frac{0.507 \times 240^2}{8 \times 2.5} = 1\,460.2 \text{ lb.}$$

The stretch produced by this tension is:

$$\frac{1\,460.2 \times 240}{0.1317 \times 16\,000\,000} = 0.1663 \text{ ft.}$$

The length of the wire without tension, therefore, is 239.9031 ft. The tension in the wire at maximum temperature with a wind pressure of 12 lb. per sq. ft. is:

$$\frac{0.652 \times 240^2}{8\,\delta} = \frac{4\,694.4}{\delta},$$

where δ is the deflection. The stretch by this tension is $\frac{0.5347}{\delta}$ ft. Equating the length with the deflection, δ, to the length without tension plus the stretch, we obtain:

$$\delta^3 + 8.721\,\delta = 48.12.$$

And from this, $\delta = 2.854$ ft.: This gives a tension, with maximum temperature and wind pressure, of 1 645 lb., or 12 490 lb. per sq. in. The greatest lateral deflection is:

$$2.854 \times \frac{0.410}{0.652} = 1.8 \text{ ft.}$$

By a similar equation, the deflection at minimum temperature with a wind pressure of 6 lb. per sq. ft. is found to be 1.434 ft., and the tension 2 746.5 lb., or 20 850 lb. per sq. in. With ice on the wire, ½ in. thick, and a wind pressure of 6 lb. per sq. ft. on the enlarged wire, the deflection is 2.06 ft., and the tension 2 956 lb., or 22 450 lb. per sq. in. The least vertical deflection occurs at minimum temperature with wind and without ice; it is 1.33 ft. This gives, for the least vertical terminal slope of the wire, 2.66 : 120 = 2.22 per cent.

The maximum vertical terminal slope was found to be 4.17 per cent. To allow for the possible inaccuracy in the erection, and in the modulus of elasticity of the wire, and for small changes of grade, the writer will assume a variation of ± 0.24% from the calculated minimum and maximum terminal slopes. This makes the new maximum slope 4.41 per cent. If the tube is made to slope 3%, then the wire hangs down 1.41% below it. This results in a bending strain. The tension with maximum vertical slope is 1 460 lb. The component normal to the tube is:

$$0.0141 \times 1\,460 = 20.65 \text{ lb.}$$

In Appendix A it is shown that the corresponding bending strain in the wire is:

$$\frac{23\,600 \times 20.65}{\sqrt{1\,460}} = 12\,730 \text{ lb. per sq. in.}$$

This occurs together with a tension of 11 088 lb., giving a total strain of 23 818 lb. per sq. in.

As the tension increases, by the reduction of the vertical deflection, this bending strain rapidly decreases. The largest lateral deflection was found to be 1.8 ft.; this corresponds to a terminal lateral slope of 3 per cent. If the radius of the side walls of the terminal channels

is made 70 ft. and their length 14 in., then the terminal tangent to the side wall has a lateral slope of 14 : 840 = 1.67 per cent. If the wire rests against the side wall, it leaves the suspender with this lateral slope. The difference between this and 3% is 1.33%, and produces a bending strain in the wire. The tension at the same time is 1 645 lb., or 12 490 lb. per sq. in. The normal force acting on the wire is 1 645 × 0.0133 = 22 lb. The corresponding bending strain is:

$$\frac{22 \times 23\,600}{\sqrt{1\,645}} = 12\,800 \text{ lb.}$$

This would produce a lateral curvature with a radius of 21 ft. 4 in.

The sliding bow, at the same time, may produce a bending strain of:

$$\frac{15 \times 11\,800}{\sqrt{1\,645}} = 4\,365 \text{ lb.}$$

The resultant of the two bending strains is:

$$\sqrt{12\,800^2 + 4\,365^2} = 13\,530 \text{ lb. per sq. in.}$$

This, together with the tension, gives a total of 26 330 lb. The actual bending strain is much less than the amount here calculated because the wire, being bent at the end of the side wall to a shorter radius than that of the side wall, lifts off it and issues from the suspender with a larger lateral slope than assumed. This greatly reduces the lateral bending strain and leaves a safe margin for error in erection.

The least vertical end slope of the contact wire when not affected by sliding bows was found to be 2.22%, or, allowing for 0.24% error from various sources, 1.98 per cent. This is reduced by the raising of the wire by two approaching sliding bows. A sliding bow with a contact pressure, Q, at the distance, A, from the end of a span, L, diminishes the weight carried by the wire to that end by $\frac{L-A}{L} Q$. If Q is 15 lb., and there are two sliding bows 30 ft. apart, one at the suspender, then the weight carried by the wire to the suspender is decreased by 28.12 lb. The tension in the wire with minimum slope is 2 746 lb. The terminal slope, therefore, is reduced 1.02 per cent.

This reduction is at one end of the suspender only. The suspender is hung from a horizontal bolt, and can swing freely around it. It will rise toward the approaching sliding bows, reducing the relative change of slope due to this cause to one-half, or 0.51 per cent.

The proper minimum slope for the calculation, therefore, is 1.47 per cent. The difference between this and the tube slope is 1.53 per cent. To produce this difference of slope by a curved top wall of 900 in. radius requires a length of 900 × 0.0153 = 13.77 in. Therefore, 14 in. is ample, with a freely swinging suspender. The 18 in. adopted is adequate for a fixed suspender.

The suspender will turn with every passing sliding bow; therefore, it is very improbable that it will get stuck by rust if it has at the start adequate play at the hinge.

The wind pressure and the lateral displacement of the suspenders, however, produce a lateral force which is a source of considerable friction at the hinge. Reasonable doubt about the freedom of motion, therefore, may be entertained, and the safest course, before experience, is to assume the suspender fixed and to make the terminal channels 18 in. long.

Provision might be made for lubricating the hinge, and then it would be safe to reduce the length of the suspender or to increase the radius of the top wall. The latter change would permit the use of a heavier sliding bow without resultant sparking.

For determining the maximum strain in the contact wire, it is necessary to know the bending strains that occur at the same time with the maximum tension. In this case, the wire rests against the top and side walls, and there are no bending strains, outside of the suspender, except from the pressure of the sliding bow.

In the terminal channels, the bending strains are due to lateral and vertical bending with known radii. The strain due to lateral bending is:

$$\frac{0.205 \times 16\,000\,000}{840} = 3\,905 \text{ lb.}$$

That due to vertical bending is:

$$\frac{0.205 \times 16\,000\,000}{900} = 3\,644 \text{ lb.}$$

The combined bending strain is:

$$\sqrt{3\,644^2 + 3\,905^2} = 5\,340 \text{ lb.}$$

If the terminal channels were omitted, the bending strain due to wind pressure would be 30 300 lb. The vertical bending strain would be about one-half as much, and the resultant of the two, 34 000 lb. per sq. in. This, with 12 800 lb. tension, would give a maximum strain of 46 800 lb. The suspension would be unsafe, even with the 84° variation of temperature here assumed. Without strain adjusters, the tensions, or the bending strains, or both, would be vastly increased. At high speeds, the suspender would receive a severe blow and the wire a violent jerk with every passing sliding bow. Most sliding bows would be broken.

It is of interest, in obtaining a practical confirmation of this theory, to calculate the strains in the contact wire of an ordinary trolley wire suspension for a span of 100 ft. of 000 B. & S. gauge, round wire, for variations of temperature of 140° fahr., with a wind pressure of 12 lb. per sq. ft. in summer, and 6 lb. per sq. ft. in winter.

Trial calculations show that a maximum deflection of about 1½ ft.

gives the smallest maximum strain in the wire. A down slope of 1½% where the wire leaves the clamp is most favorable.

The strain, with maximum temperature and wind pressure, is 4 000 lb. tension and 27 750 lb. bending, giving a total strain of 31 750 lb. per sq. in. At minimum temperature, with wind, and with two sliding bows of 15 lb. contact pressure 30 ft. apart, the tension is 15 600 lb. and the bending strain 16 900 lb., giving a total strain of 32 500 lb. per sq. in. The terminal down slope of the wire, at maximum temperature, without wind, is 6%; at high speed, this, though reduced by the approaching sliding bow, when without adequate transition curve, is dangerous to the wire, the clamp, and the sliding bow. The suspension, therefore, is only suitable for moderate speeds. The above maximum strains are only moderately safe. These results agree with actual experience. With smaller wires, the lateral deflections and the strains are larger, and the degree of safety is reduced.

The saddle suspension for 240-ft. spans, here proposed, gives much smaller maximum strains in the contact wire, and, for all deflections, provides transition curves of large radius which make high speeds harmless.

APPENDIX C.

SLIDING BOWS FOR HIGH-SPEED ELECTRIC RAILWAYS.

The contact wire which forms the track for the sliding bow is suspended either at short or long intervals. In the former case, the weight of a half span of contact wire is generally much less than the upward pressure of the sliding bow, called the contact pressure. The wire, therefore, is bent up by the bow beyond the supports. In the latter case, the wire of a half span weighs more than the amount of the contact pressure; it is lifted by the bow from its normal sag to a position still below the horizontal. In all cases, the bow moves along vertical curves. At high speeds this produces a considerable amount of centrifugal force, which, according to its up or down direction, increases or reduces the contact pressure. The increase should not be so large as to produce dangerous bending strains in the wire; the reduction should not be so large as to cause separation of the bow from the wire and consequent sparking. The centrifugal force is proportional to the weights of the parts of the bow and of its supporting frame which move in curves, and to the square of their speed, and inversely proportional to the radii of curvature of their motion. It is given by the equation:

$$C = \Sigma \frac{w}{g} \frac{v^2}{R} = \frac{v^2}{g} \Sigma \frac{w}{R}$$

where C is the centrifugal force, in pounds, v is the train velocity, in feet per second, g is 32.2 ft., $\frac{w}{R}$ is the weight of a part of the sliding bow or of its frame divided by the radius of its motion.

$\Sigma \frac{w}{R}$ is the sum of all these quotients for the sliding bow and its frame. If $\Sigma \frac{w}{R} = \frac{W}{r}$, where r is the radius of curvature of the motion of the contact point, then W is the equivalent weight of the sliding bow and its frame; it is the weight which, if moving as the contact point, produces the same centrifugal force as the sliding bow and its frame. With the saddle suspension, r, at the center of the suspender, is conveniently made from 5 to 12 ft. Here the sliding bow presses against the suspender, and a large contact pressure will not endanger the wire. In the terminal channels of the suspenders the wire is generally convex downward, and the centrifugal force reduces the contact pressure. r can here be made 75 ft. with, and 40 ft. or more without, strain adjusters. For a speed of 80 miles per hour, an equivalent weight, W, of 2.5 lb. and a radius, r, of 75 ft., the centrifugal force is $C = \frac{2.5 \times 117.33^2}{32.2 \times 75} = 14.25$ lb. A minimum

static contact pressure of 15 lb. will be reduced by the centrifugal force to 0.75 lb., and will be adequate to prevent interruption of contact at the suspenders.

For a speed of 50 miles per hour, an equivalent weight, W, of 3 lb. and a radius, r, of 40 ft., the centrifugal force is $C = \frac{3 \times 73.33^2}{32.2 \times 40}$ = 12.52 lb. A static contact pressure of 15 lb., therefore, is ample to prevent interruption of contact at the suspenders.

Plate CXI shows a sliding bow of 3 lb. equivalent weight when 6 ft. long with 8 ft. range of vertical motion. The bow is made of three aluminum channels, and is 6 ft. long, over all. It has a shallow space for grease which latter must be sticky so as not to be thrown out by centrifugal force. The bow proper is connected by hinges to two radial arms. The latter are bolted to a tubular shaft. The shaft rests in bearings carried by the ends of two bent tubes. Each of the bent tubes is held by a pin and a sleeve. The sleeve forms the upper hinge of the main diamond frame. This diamond frame has extensions upward giving support to the top of the tubes. The shaft carrying the radial arms also carries at each end two springs. The free ends of the larger or main springs are inserted into holes in the hubs of the bent tubes. The free ends of the smaller springs rest against the lower sides of these hubs. The main springs press the radial arms up; the smaller reverse springs press them down.

The frame below A-B can be designed so that its upward pressure, when it rises with uniform speed, is approximately constant and produces a contact pressure of 15 lb. for sliding bows intended for maximum speeds of 50 miles an hour. The contact pressure required to make the frame fall with uniform speed is 15 lb. plus twice the friction. Assuming the friction at 2 lb., the contact pressure with uniformly falling frame is 19 lb.

In the following 15 lb. is called the active or minimum static contact pressure, and 19 lb. the passive or maximum static contact pressure. The equivalent weight of an ordinary diamond-frame sliding bow can be greatly reduced by using an aluminum bow and light vanadium steel tubing with McAdamite connection castings. It will hardly be possible, however, to make it less than 6 lb. for a bow with 8 ft. range of vertical motion. This, as above shown, is too much for the highest speeds.

With the writer's modified frame, the two radial arms carrying the bow are ordinarily in an intermediate position, produced by proper adjustment of the springs. When the bow approaches the suspender of the saddle suspension it rises, together with the frame, the contact pressure being 15 lb. After the bow passes the suspender, the frame continues to rise; the bow itself, which rose as it approached the suspender, is made to fall as it passes the central part of the

latter. The contact pressure at the central part of the suspender is between the latter and the bow, and, at high speeds, exceeds 100 lb. Beginning at the suspender, the radial arms turn down, and the torque of the springs increases. This increasing torque of the springs determines the amount of the contact pressure. Due to the presence of these springs, the contact pressure depends on their rigidity and the direction of the radial arms. The heavy frame below the springs, by its inertia, continues to move up, but with a retarded motion, because the increasing contact pressure (together with the weights) is larger than the constant force pushing it up. After the upward velocity of the frame is reduced to 0 (which occurs, as will be shown, about 0.15 sec. after passing the bow), it begins to move down with an accelerated motion. The radial arms, which have been turning down, begin shortly after to turn up again, and they reach not only their original angle of slope, but rise beyond it. The contact pressure decreases to less than the minimum static pressure, and the downward motion of the frame is retarded; it soon stops, and begins to go up again. After a few oscillations, the damping action of the friction stops the swinging of the radial arms.

It is evident, from the foregoing, that the sliding bow and the radial arms alone follow closely the sharp curves in the motion of the contact point. The sliding bow follows the curves accurately, the parts of the radial arms nearer the shaft move in a different manner and their weight is less important than that of the bow.

The writer, in his paper entitled "Overhead Contact Lines," has shown that the radial arms are equivalent to a weight one-third as large moving like the sliding bow. The sliding bow proper weighs 1.72 lb. The equivalent weight of the sliding bow and radial arms is 3 lb. In this design the two radial arms are bolted to the shaft, they therefore always move through the same angle. The whole sliding bow moves like the contact point. The equivalent weight of the frame largely determines, as will appear from the following calculations, the needed range of relative vertical motion of bow and shaft. The radial arms sometimes point in the direction of the train motion, sometimes backward.

There may be a strong head wind. The wind pressure on the sliding bow is then due to the sum of the velocities of wind and train. If the radial arms point forward, this wind pressure increases the upward slope until it is balanced by the change in the torque of the springs. The amount of the contact pressure is not directly affected thereby. If the radial arms point backward, the wind pressure reduces their upward slope until it is balanced by the changed torque of the springs. In the former case the remaining available upward range, in the latter the downward range, of motion is reduced. It is desirable, therefore, to limit as much as possible the change in the slope

of the radial arms produced by wind pressure. As will appear from the following calculations, this is attained by the use of reverse springs. The action of the reverse springs is limited to only the upper part of the range of motion of the radial arms.

The reverse springs used in the design here described have the same stiffness as the main springs. The change in torque for a given arc of motion, therefore, is twice as much within the range of their action as outside of it.

For showing the range of adaptation of the sliding bow, the writer will assume an unfavorable case, namely: A span of 220 ft., a maximum vertical deflection of 4 ft., a 000 B. & S. gauge wire, and a train speed of 50, with an occasional head wind of 80, miles an hour.

The radial arms are 30 in. long from center of bow hinge to center of shaft. The springs are adjusted so that the bow hinges, which are on the center line of the sliding bow, are 11 in. above the center line of the shaft when the contact pressure is 15 lb., and the train is moving at a speed of 50 miles an hour, while there is no wind, and the radial arms are pointing backward. In this case the wind pressure on the bow and the radial arms is due to the train velocity only; it is equivalent to 3.38 lb. acting on the bow. The weight of bow and radial arms is equivalent to 2.75 lb. at the bow and 1.85 lb. at the shaft. The horizontal distance between the bow hinges and the shaft is:

$$\sqrt{30^2 - 11^2} = 27.91 \text{ in.}$$

The resultant torque of the main and reverse springs must be equal and opposite to the bending moment of the contact pressure, the weight and the wind pressure on the bow and arms, or:

$$(15 + 2.75) \times 27.91 + 3.38 \times 11 = 532.7 \text{ in-lb.}$$

When the radial arms are lowered, the torque of the main springs (pushing them up) increases, that of the reverse springs (pushing them down) decreases. The contact pressure, which is the main force balancing the torque, therefore increases with the lowering of the arms. To avoid interference of the contact wire and the main springs, the bow pins must be at least 3 in. above the center of the shaft. The downward range of motion from the above position, therefore, is 8 in. It has been found by trial that this range is adequate if the contact pressure increases 30 lb. while the bow moves through the whole of it.

To prove the adequacy of this range the writer will choose the springs so that the contact pressure does increase 30 lb. while the bow turns down to 3 in. above the center of the shaft, and will then calculate the actual relative motion of the bow and shaft when the bow advances from the suspender toward the other end of a span, and will thereby prove that the bow does not move beyond the available range.

In the lowest position of the bow, its horizontal distance from the shaft is $\sqrt{30^2 - 3^2} = 29.85$ in. The torque of the springs must balance the moment of the weight, the contact pressure, and the wind pressure around the shaft; or,

$$\text{torque} = (45 + 2.75)\ 29.85 + 3.38 \times 3 = 1\,435.5.$$

The increase in the torque of the springs during this motion, therefore, is:

$$1\,435.5 - 532.7 = 902.8 \text{ in-lb.}$$

The angle, a, of the radial arms (from shaft to hinges) with the horizontal, is given by sin. $a = \frac{3}{30}$, or $a = 5°\ 44.36'$. The angle, b, for the first position, is given by sin. $b = \frac{11}{30}$, or $b = 21°\ 31.63'$, and $b - a = 15°\ 47.27'$. The length of the corresponding arc described by the bow is 8.266 in. The reverse springs will be adjusted so that they act through only the first quarter of this arc and are equally stiff with the main springs. The change in torque through the first quarter of the motion, therefore, is twice as much as in any succeeding quarter. The total change in torque, therefore, is as much as in five-fourths of an arc of 8.266 in. with only one spring, or in 10.332 in.

The change in torque per inch of arc is $902.8 : 10.332 = 87.38$ in-lb. This applies to the last three-quarters of the motion. During the first quarter the change in torque per inch of arc is 174.76 in-lb. From this the size and length of the springs will be determined, in the following.

The lowest position of the sliding bow will evidently be reached when the radial arms are pointing backward and are turned down by a strong head wind. Assuming the wind velocity 80 and the train velocity 50, their relative velocity is 130 miles an hour. This gives a wind pressure of 45.6 lb. per sq. ft., or, on the sliding bow, 22.8 lb., its area, together with the mean equivalent area of the radial arms, being $\frac{1}{2}$ sq. ft. By trial equations between torques and moments, it is found that the radial arms are lowered 1.05 in. below the position corresponding to 15 lb. contact pressure without head wind. With this head wind, the bow, when it passes the suspender, is only 9.95 in. above the shaft. Its downward range of motion relative to the shaft, therefore, is only 6.95 in. When the bow is 9.95 in. above the shaft, the angle of the radial arms with the horizontal is $19°\ 22.2'$. The available range of downward motion, measured in degrees, is $19°\ 22.2' - 5°\ 44.36' = 13°\ 37.84'$. The corresponding arc of the bow measures 7.137 in. Of this arc, 0.937 in. is under both springs with double torque, the remainder, or 6.2 in., under the main spring only. The contact pressure of 15 lb. exists now when the bow is only 9.95 in. above the shaft. The contact pressure in the lowest position is found

from the equation between the torque and the moment of the acting forces. The equation is:

$$(2.75 + X)\ 29.85 + 22.8 \times 3 = 1\,435.5$$

where X is the contact pressure. From this, $X = 43.03$ lb. The increase in contact pressure during the down motion of 6.95 in., therefore, is $43.03 - 15 = 28.03$ lb. Of this motion, 0.89 in. is under the reverse springs, and 6.06 in. under the main springs only. Counting the first part double, we have 7.84 in. Dividing 28.03 by 7.84 we obtain, where only the main springs act, 3.58 lb. as the change in the contact pressure per inch of vertical relative motion of bow and shaft, and, where the reverse springs also act, twice as much, or 7.16 lb.

The actual relative motion of bow and shaft, after the bow passes a suspender, will now be calculated. Before the bow reached the suspender, it and the shaft were moving up together along the contact wire. It is necessary to ascertain the upward velocity of the shaft at the moment when the suspender is passed. The most unfavorable case is that with maximum deflection of the contact wire. For this case the deflection is 4 ft. and the span is 220 ft. The terminal down slope of the contact wire, therefore, is $\frac{8}{110} = 7.273$ per cent. The weight of a half span of the wire is 55.8 lb. This terminal slope is reduced by the presence of a sliding bow in the span. This sliding bow lifts the wire. The suspenders are carried either by brackets or a span wire construction between pairs of poles. Their resistance to a small longitudinal motion of the suspenders is small. The tension in the contact wire, therefore, will be but little reduced by the presence of a sliding bow in a span. It will be assumed, for the present, to be constant. The contact wire carries 55.8 lb. to the suspender; when a sliding bow with a contact pressure of 15 lb. approaches, this end shear or vertical component of the tension in the wire is reduced to $55.8 - 15 = 40.8$ lb. The end slope of the wire is reduced to $\frac{40.5}{55.8} \times 0.07273 = 0.05318$. The train velocity is 73.33 ft. The velocity of upward motion of the shaft at the suspender, therefore, is $0.05318 \times 73.33 = 3.896$. The sliding bow and the radial arms are turned down by the suspender; the contact pressure increases; the upward motion of the shaft, therefore, becomes a retarded motion. The different parts of the frame have a different upward velocity and the retardation produced in them is also different. The inertia of the whole frame (exclusive of bow and radial tubes, but inclusive of their hubs) was calculated from a design and found to be equal to that of a weight of 16.1 lb. moving with the vertical velocity of the shaft carrying the radial arms. This estimate is based on the use of nickel or vanadium steel tubing of not more than the thickness needed for

ample strength. A vertical force of 1 lb., acting on the frame, therefore, will produce an acceleration of the shaft of 2 ft. per sec.

Considering now what happens after the sliding bow passes the suspender, it is evident that the bow and the radial arms are turned down by the suspender and move along the wire, which latter is raised by the contact pressure. The frame and the shaft continue to rise by their inertia. The initial upward velocity of the shaft is 3.896 ft. Taking an interval of $\frac{1}{40}$ sec., the contact pressure at the start is 15 lb.; it increases during this time by an amount depending on the relative motion of shaft and bow. The retardation of the shaft depends on this increase of the contact pressure. The position of the sliding bow at the end of $\frac{1}{40}$ sec. depends on the contact pressure then existing. A formula might be developed for finding the relative vertical motion of shaft and bow, but a more convenient and shorter method is to assume the relative motion, to find the corresponding contact pressure at the end of the time interval, and to calculate from it the consequent motion of shaft and bow and their relative motion. If the result does not agree with the assumption made, another relative motion must be assumed, and the calculation repeated. After two calculations the proper value can generally be found closely by interpolation. This, though circuitous, is believed to be shorter than the development of formulas for the many different cases which must be considered. Assuming, then, the relative motion of shaft and bow during the first $\frac{1}{40}$ sec. to be 2 in., the contact pressure during the first 0.89 in. of this relative motion increases 7.16 lb. per in.; after this it increases 3.58 lb. per in.; at the start it is 15 lb. At the end of the time interval it is $[15 + (3.58 \times 0.89)] + (3.58 \times 2) = (18.19 + 7.16) = 25.35$ lb. The average contact pressure during the interval is $\frac{15 + 25.35}{2} = 20.175$ lb. This is 5.175 lb. in excess of the 15 lb. which would allow uniform upward motion of the frame. The average retardation of the motion of the shaft produced thereby is 10.35 ft. The consequent reduction of velocity during $\frac{1}{40}$ sec. is 0.259 ft. The end velocity of the shaft is $3.896 - 0.259 = 3.637$ ft. The average velocity during this interval is $3.896 - 0.130 = 3.766$ ft. The upward motion of the shaft, in inches, is $\frac{3.766 \times 12}{40} = 1.130$ in. The contact pressure at the end of the interval is 25.35 lb. The sliding bow has advanced from the center of the suspender by $\frac{73.33}{40} = 1.8333$ ft. To obtain a convenient formula for finding the position of the sliding bow, with a contact pressure, P, after n intervals of $\frac{1}{40}$ sec., the distance of the sliding bow from the near end of the span is $n \times 1.8333$ ft. Of the pressure, P, there goes to the near end of the

span, $P\frac{(220 - 1.8333\,n)}{220}$. The weight of the assumed wire is 0.507 lb. per ft. One-half the span (or 0.507×110) is carried to each end. The load carried to the near end of the span is $0.507 \times 110 - P$ $\frac{P \times 1.8333\,n}{220}$.

This is the shear at the end of the span, or the vertical component of the tension in the wire. The wire between the sliding bow and the near end of the span hangs in a curve. The chord of this curve is parallel to the tangent in its center. The direction of this tangent depends on the shear at this point and the tension in the wire. This shear is equal to the end shear less $\frac{n \times 1.8333 \times 0.507}{2}$. Subtracting this from the end shear and reducing the result to convenient form, we obtain $(55.8 - P)\ \left(1 - \frac{1.8333\,n}{220}\right)$ lb. The down slope of this tangent is less than the terminal slope of 0.07273 in the ratio of this shear to the shear of 55.8 lb. Therefore, it is

$$\frac{(55.8 - P)\ \left(1 - \frac{1.8333\,n}{220}\right)}{55.8} \times 0.07273.$$

The drop from the suspender to the contact point is equal to the slope multiplied by the distance, or, after reduction and expression in inches, $(55.8 - P)\ (1 - 0.008333\,n)\ 0.0287\,n$. From this formula we get the drop of the bow after $\frac{1}{40}$ sec. for the assumed relative motion of shaft and bow of 2 in. by making $P = 25.35$ and $n = 1$. This gives for the drop of the bow 0.867 in. We found that the shaft rises 1.130 in. in the same time interval. This gives 1.997 in. for the relative motion of bow and shaft in the first $\frac{1}{40}$ sec. This is so close to the assumed 2 in. that no further trials are necessary.

For the second $\frac{1}{40}$ sec. the relative motion of shaft and bow is assumed to be 1.5 in. For the relative motion during $\frac{1}{20}$ sec., this gives $1.997 + 1.5 = 3.497$ in. The contact pressure at the end of this interval is $18.19 + (3.497 \times 3.58) = 30.72$ lb. The average contact pressure during the second $\frac{1}{40}$ sec. is 28.04 lb. This is 13.04 lb. in excess of the pressure which would allow a uniform rise of the shaft. This produces an average retardation of 26.08 ft., and a reduction of velocity in the interval of 0.652 ft. The velocity at the end of the previous interval was 3.637 ft. The upward velocity of the shaft at the end of the second $\frac{1}{40}$ sec. is $3.637 - 0.652 = 2.985$ ft. The average velocity during the interval is $3.637 - 0.326 = 3.311$ ft. The consequent upward motion of the shaft is 0.993 in. The previous upward motion of the shaft was 1.130 in. The total upward motion of the shaft during $\frac{1}{20}$ sec., therefore, is 2.123 in. From the above formula

the downward motion of the bow is found by making $P = 30.72$ and $n = 2$. The downward motion of the bow during $\frac{1}{20}$ sec. is 1.416 in. The relative motion of shaft and bow during $\frac{1}{20}$ sec., therefore, is $2.123 + 1.416 = 3.539$ in. A repetition of the calculation with a slightly larger assumption for the relative motion gives approximately:

Motion of shaft in $\frac{1}{20}$ sec	2.123 in.
Motion of bow	1.407 "
Total relative motion in $\frac{1}{20}$ sec	3.530 in.

The calculation, continued in the same manner, shows that the relative motion of shaft and bow reaches its maximum after 0.15 sec., and is then 5.99 in. After this the radial arms begin to move up again and they reach their original slope corresponding to a relative motion 0 after 0.47 sec. The arms rise further until the vertical distance between bow and shaft is 1.626 in. more than at the start. The contact pressure is then only 3.17 lb. This occurs 0.70 sec. after passing the suspender. The arms begin then to move down a second time. After a few swings the oscillation is stopped by the friction. This calculation is not accurate mainly because the tension in the contact wire, which was assumed constant, is slightly reduced by the action of the sliding bow. This reduction, however, is small, partly because the sliding bow during the first oscillation, which is the largest, is near the end of the span, and partly because the suspenders can move easily a fraction of an inch in the direction of the track. The margin for the downward motion is about 1 in.; this will be reduced by the reduction in tension in the contact wire.

It is evident that the amount of the initial upward velocity of the shaft when the bow passes the suspender is a very important factor deciding whether the range of relative vertical motion of bow and shaft allowed is adequate. This initial velocity depends on the terminal slope of the wire, the ratio between static contact pressure and the weight of a half span of wire, and especially on the train velocity.

When the radial arms are turned forward, a head wind of 80 and a train speed of 50 miles an hour cause a rise of the bow. With 15 lb. contact pressure, the bow rises to an elevation of 12.8 in. above the shaft. It will rise approximately 1.9 in. more during the oscillation. There is plenty of upward range of motion to allow this rise.

For obtaining a small equivalent weight for the bow and radial arms, it is important that the radial arms form a small angle with the horizontal. When the bow follows a curve in the contact wire, an approximately vertical acceleration of $\frac{v^2}{r}$ must be given to it by an external force, where v is the train velocity and r is the radius of curvature of the motion of the bow. This acceleration is produced by

the turning of the radial arms. This turning moves the bow normal to the arms. The vertical component of its motion is only equal to the motion multiplied by the cosine of the angle, a, of the radial arms with the horizontal. The acceleration of the bow and of the ends of the radial arms, therefore, must be equal to $\frac{v^2}{r \cos. a}$. The variation, P, of the approximately vertical contact pressure produces this acceleration; this pressure forms an angle, a, with the acceleration, and its component in the direction of the acceleration is $P \cos. a$. The force to produce the acceleration is equal to the mass to be moved multiplied by the acceleration, or

$$P \cos. a = M \frac{v^2}{r \cos. a}, \text{ or } P = M \frac{v^2}{r \cos.^2 a}.$$

M is the mass which if placed at the bow offers the same resistance to turning as the bow and the radial arms. M is approximately equal to the mass of the bow plus one-third of the mass of the arms. It is evident that P, or the variation of contact pressure due to centrifugal force, is greatly increased if the angle, a, is large. To obtain a small variation of contact pressure due to centrifugal force, or, in other words, a small equivalent weight of the sliding bow, the arms should form a small angle with the horizontal. This is the main reason why the reverse springs, which greatly reduce the variation of elevation of the bow above the shaft, are necessary for obtaining a small equivalent weight. The angle of the radial arms with the horizontal when the sliding bow passes the suspender is the only important one in calculating the equivalent weight of the sliding bow. The angle, a, with a head wind of 80, and a train velocity of 50, miles per hour with the radial arms turned forward, and, when the bow passes the suspender, is given by sin. $a = \frac{12.8}{30} = 0.4267$. This gives $\cos.^2 a = 0.8179$, and $\frac{1}{\cos.^2 a} = 1.223$. The equivalent weight, $M g$, for the bow and radial arms is 2.4 lb. This is increased, due to their slope when at the suspenders, to $2.4 \times 1.223 = 2.94$ lb. Allowing for some inaccuracy, it may be 3 lb.

Referring to the main springs: There is in each main spring a maximum torque of 718 in-lb. Their strength is given by the equation, $718 = \frac{\pi d^3}{32} s$, where d is the diameter and s the strain per square inch. Taking s, for hardened spring steel, $= 100\,000$ lb., then $d = 0.418$ in. The length of the spring is found by the equation, $f = \frac{64}{\pi} \frac{P l r^2}{E d^4}$. In this equation, r is 30 in., f is the arc through which the bow moves by the application of the force, P, acting along the

tangent with the radius, r. It has been found that, for $f = 1$ in., $P \times r$ must be 87.38 in. This gives for l, the length of the spring, 33.2 in. In the same manner, the reverse spring, shown on Plate CXII, was calculated.

Higher speeds than 50 miles an hour, together with a head wind of 80 miles an hour, are only practicable with trains of cars. Such trains have more than one sliding bow. The wire, therefore, is lifted much more than with one bow. The initial upward velocity of the shaft when the sliding bow passes the suspender is thereby much reduced, and the same available range of downward motion will generally be adequate. On roads having high train speeds, substantial steel poles will mostly be wanted; with such it is always advantageous to use strain adjusters which permit longer spans or smaller deflections of the contact wire. Either of these diminish the vertical velocity of the shaft when the sliding bow passes the suspender, and the assumed range of relative motion of shaft and bow becomes adequate in spite of the higher speed. The higher speed also requires longer radii of vertical curvature of the contact wire, for the purpose of avoiding jumping of the sliding bow. These longer radii become practicable only if strain adjusters are used.

The sliding bow here described is also suitable for the catenary suspension. Though the wire appears to be straight where this suspension is used, it is bent up by the contact pressure, especially if the suspenders are near together. With a heavy sliding bow, and a slack wire at high temperature, the curvature of the motion of the sliding bow is sharp just before a suspender is reached, and the sliding bow jumps at high speed. A light sliding bow will evidently produce less centrifugal force and less variation of contact pressure, and consequently less jumping. It will run smoothly at much higher speeds than a heavy one.

There are inevitably vertical curves and changes of direction of the contact wire at low overhead crossings and tunnel entrances. These changes will cause much less trouble with a light sliding bow. With catenary suspension and short spans between poles, a sliding bow 4 ft. long, with radial arms 2 ft. long, can often be used. Such a sliding bow can be designed for an equivalent weight of 2 lb. Such a bow will run smoothly at very high speeds.

With the more uniform contact pressure of a light bow, a much smaller static contact pressure can be used. The result will be less wear and greater durability of bow and wire. The increase in the first cost of a diamond-frame bow caused by the modification here proposed will be in all cases amply repaid by the reduced cost of construction and maintenance of the contact line.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

REINFORCED CONCRETE FOUNDATIONS OVER EXCAVATIONS ON PAVED STREETS.*

By John McNeal, M. Am. Soc. C. E.

Constant excavations on the paved streets of Easton, Pa., and numerous depressions formed over previously excavated trenches, have called the writer's attention to the necessity of providing some means for protecting the surface of the street from gradual settlement below the general level of the adjoining paving.

No matter how carefully the back-filling of a trench is done, there is bound to be a settlement of the earth replaced in the trench, and in some cases this settlement has not begun to show for a year or more after the paving has been replaced.

In order to avoid settlement of the surface, the foundation for repaving over all trenches has been reinforced with expanded metal. For a trench not more than 20 in. in width, the writer uses expanded metal, of 3-in. mesh and No. 10 gauge steel, having a cross-sectional area of not less than 0.185 sq. in. per ft. in width.

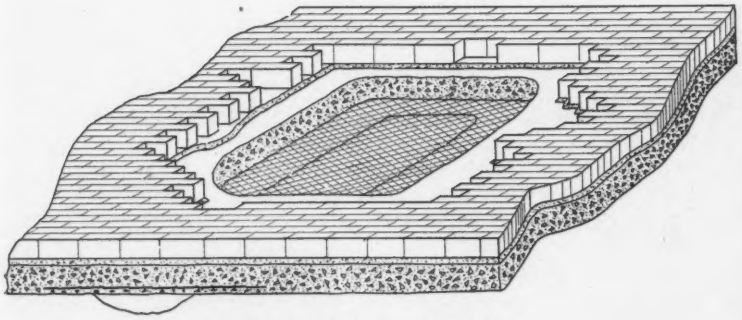
After the trench is properly back-filled, the old concrete is removed for a distance of at least 1 ft. beyond each side of the trench, and expanded metal is placed over the entire opening. A thickness of 6 in. of concrete, mixed in the proportion of 1 part Portland cement, 3 parts sand, and 5 parts broken stone, is placed over and around the

*This paper will not be presented at any meeting, but written communications on the subject are invited for publication with it in *Transactions*.

expanded metal in such a manner that the metal is embedded in it, 1½ in. above the base and 4½ in. below the surface.

After the concrete is thoroughly rammed to an even surface, the paving material is replaced on this surface to conform with the adjoining paving.

These requirements met with some opposition at first from corporations and local contractors who are constantly digging up the paved streets for new mains and repairs, but now all excavated trenches are repaved with the expanded metal reinforcement.



REINFORCED CONCRETE FOUNDATIONS
OVER
EXCAVATIONS ON PAVED STREETS.

FIG. 1.

The cost of this foundation per linear foot of trench is about 37½ cents more than that of plain concrete.

Assuming the working strength of the steel to be 20 000 lb. per sq. in., and allowing for the shape of the metal, which distributes the load over 20 in. of trench, a wheel load of from 650 to 700 lb. would be supported safely without the aid of the back-filling below the foundation.

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NOTE ON THE IMPROVEMENT OF THE MISSISSIPPI RIVER.*

By W. G. Price, M. Am. Soc. C. E.

During the past twenty-seven years much work has been done on the Mississippi River between Cairo and New Orleans, but comparatively little has been accomplished in the way of permanent improvement, except in the construction of levees.

The revetting of caving banks by a continuous mattress has certainly not proven to be a permanent form of improvement in many places, and whenever such a mattress is located for a long time in a place where it is opposed to the force of the river flow, it must fail. Much of the mattress which has been placed was constructed in such a manner that, if not carried away bodily by the first flood, it would disintegrate and float away stick by stick, owing to the fastenings being of metal, and soon destroyed by corrosion.

To design structures which will not be carried away has been a difficult problem, but such have been built, and, in the light of experience, still better designs can now be made.

Some years ago the writer was engaged in improving the Harbor of New Orleans. This was done by works which formed what were intended to be fixed points in the bank of the river and could not be

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carried away. The writer believed then that this was the proper way to secure a permanent improvement of the whole river. Some of the work at these fixed points was put in with such details of construction that they should have failed before this time; the writer, however, believes that permanent works on this plan can now be constructed which will confine the river so as to prevent it from wandering away from the place where it is desired to hold it, and also greatly improve the navigable depth. These fixed points would have to be located at various distances apart, depending on the degree of curvature of the river, but the number required would not entail a prohibitive expense, provided each one was put in so as to be a permanent work and not require constant repairs, and it is with the view of giving a hint of how to make such work permanent that this paper has been written.

The Mississippi has shown that it has power to destroy and carry away almost everything that Man has constructed to oppose it. By using a little strategy in design, however, the river can be compelled to use its mighty power to dig foundations for permanent improvement works. This can be done, and has been done, by making the form of construction of these works to be fixed points, so that the river cannot disintegrate them, or move them bodily down stream, but must undermine them; it is known that it can, and will, and it is by taking advantage of this undermining power that the point can be made a fixture.

By designing the structure so that only wood and stone, properly bound together, form its permanent parts, the forces acting against it can do nothing but undermine it and sink it in the sand, while more of the same material is piled on top of that which is sinking, and a depth of foundation is soon reached which the river will not cut under. In this way the flowing water will sink a large structure to a depth which will give a permanent foundation, in the same way that a pile is sunk with a jet of water.

The work must be well connected to the levee, and must extend well out on the bed of the river.

When the writer was building the dam from Turnbulls Island across Red River, in Louisiana, he had no fear of the river being able to destroy the work, or cut around it, and he believes now that it was a great mistake to destroy this dam, by dredging a channel through it, after it was more than half completed.

The writer believes that the power of the flowing water in any silt and debris-bearing stream can be utilized and directed, by a properly designed structure, so that it will dig a permanent foundation for such a structure, and that a sufficient number of improvement works have been built, and have been tested for a sufficient length of time, in the Mississippi and other rivers, to indicate the proper details of construction.

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NOTES ON RAINFALL AT SAVANNAH, GEORGIA.*

By J. de Bruyn-Kops, M. Am. Soc. C. E.

The writer would not have deemed this paper of sufficient interest to present to the Society were it not for the fact that A. Prescott Folwell, M. Am. Soc. C. E., in a recent book* states that:

"Professor Talbot gives as a formula of maximum rates of rainfall in the eastern part of the country $R = \frac{105}{T + 15}$, which agrees quite closely with Plate IV, South Atlantic States, up to 30 min., but gives too small values for longer periods."

The curve on Plate IV, page 125, of that book shows "Rates of Rainfall Storms of the Second Class"; and, from the discussion at the bottom of page 56, it is inferred that "Storms of the Second Class" are those that give a certain rate of rainfall approximately five times in ten years, which is equivalent to once in two years. Now, as Savannah is about at the center of the territory named, this curve should apply to that city. The writer, therefore, compared it with some data he had worked out in 1896, while he was Assistant City Engineer of Savannah, and, finding that it did not agree with the results obtained at that time, he obtained from the United States Weather Bureau the data relating to all storms occurring during the years 1889 to 1906, inclusive, as recorded by the automatic rain gauge at Savannah, which

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*"Sewerage," 1907 Edition, Article 17, p. 45.

gave a precipitation equal to or greater than 0.25 in. in 5 min. or 0.75 in. in 1 hour. These data have been put into the shape here presented, in the hope that they may be found useful to others engaged in drainage works.

Referring to the quotations given above, it seems to the writer that such expressions as "in the eastern part of the country," and "South Atlantic and Gulf States" are entirely too comprehensive in their scope, and that it will be found that no single formula is even approximately correct for such a large area as that indicated; therefore, in promulgating such formulas, it should be distinctly stated from what data and locality they were deduced, as well as the method of deduction.

The following is the method of treating the data used by the writer: As received from the United States Weather Bureau, the data were in the form of accumulated amounts of precipitation for each 5 min. that the storm lasted; a sample case being that of the storm on December 8th, 1890, which is here reproduced:

Minutes.	5	10	15	20	25	30
Accumulated precipitation	0.20	0.32	0.50	0.75	0.95	1.03

Now, it is evident that the natural course of this storm presents rates of precipitation as follows:

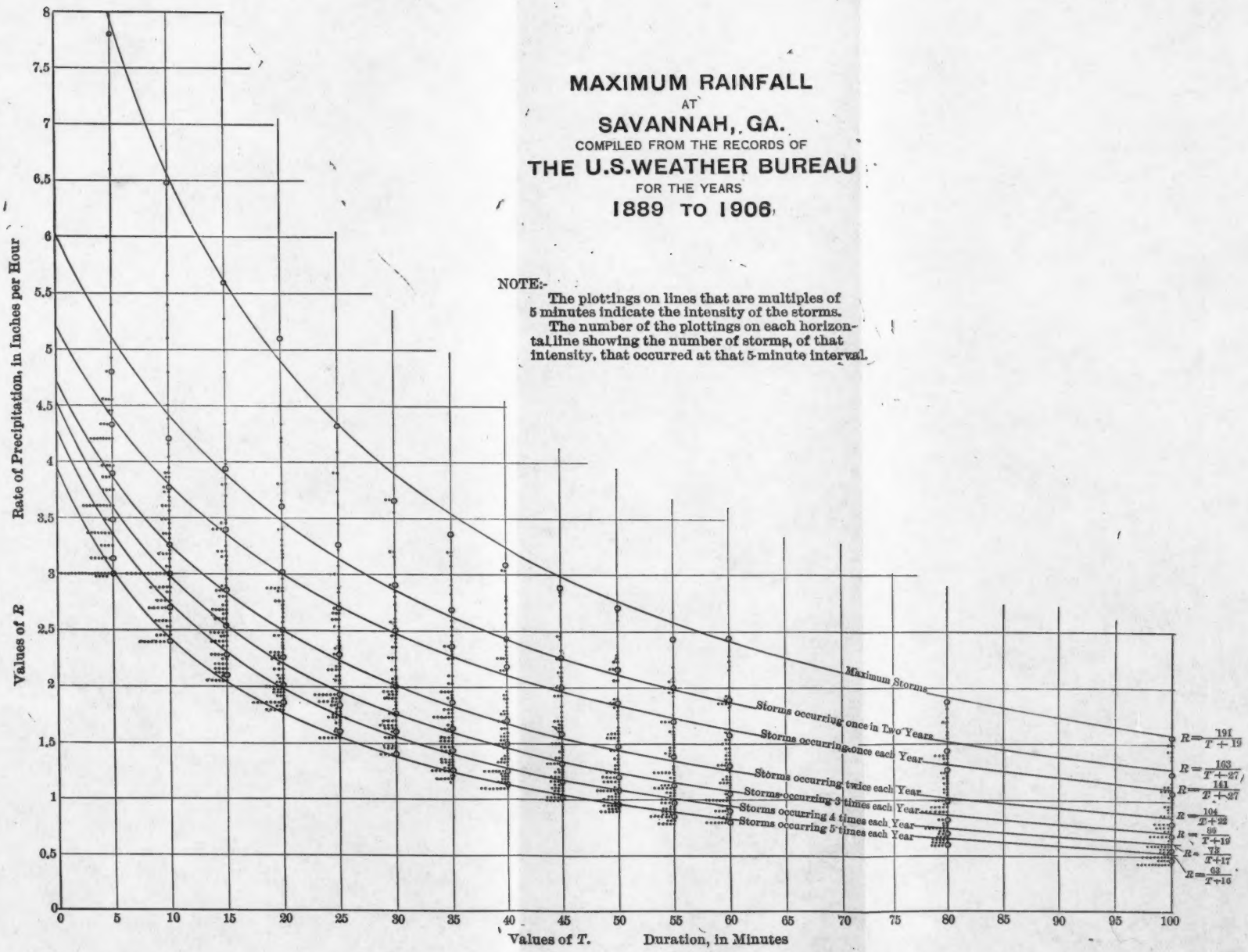
Minutes	5	10	15	20	25	30
Accumulated precipitation	0.20	0.32	0.50	0.75	0.95	1.03
Rate, in inches per hour	2.40	1.92	2.00	2.25	2.28	2.06

The greatest rate of precipitation is 2.40 in. per hour for the space of 5 min. It has seemed to the writer, however, that the main consideration is not the rates of fall given by the natural course of the storm, but the maximum rates for the different durations; therefore, the storm data have been rearranged so as to exhibit this maximum, as follows:

Minutes	5	10	15	20	25	30
Accumulated precipitation	0.20	0.32	0.50	0.75	0.95	1.03
Precipitation in each 5 min.	0.20	0.12	0.18	0.25	0.20	0.08
Maximum accumulated precipitation	0.25	0.45	0.63	0.75	0.95	1.03
Maximum rate of precipitation.	3.00	2.70	2.52	2.25	2.28	2.06

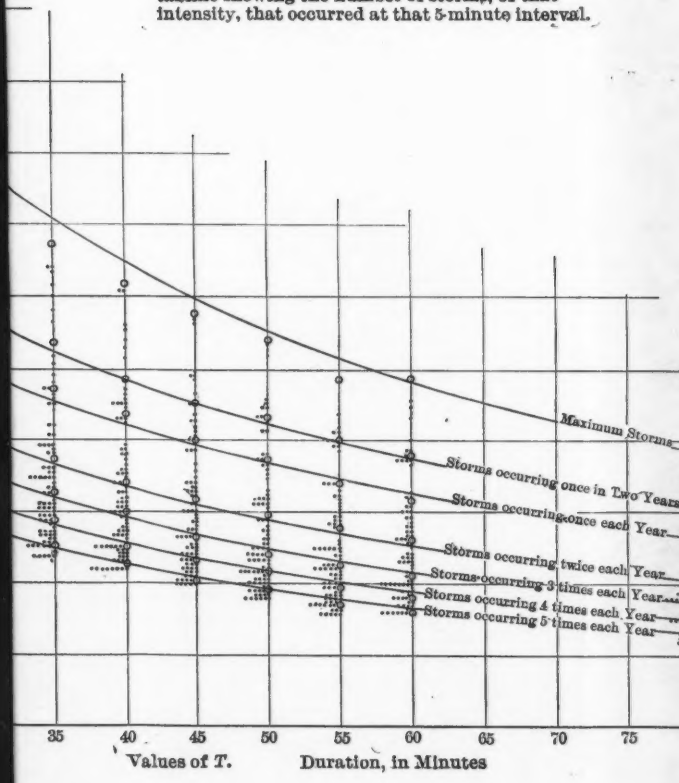
MAXIMUM RAINFALL
AT
SAVANNAH, GA.
COMPILED FROM THE RECORDS OF
THE U.S. WEATHER BUREAU
FOR THE YEARS
1889 TO 1906

NOTE:-
The plottings on lines that are multiples of 5 minutes indicate the intensity of the storms.
The number of the plottings on each horizontal line showing the number of storms, of that intensity, that occurred at that 5-minute interval.



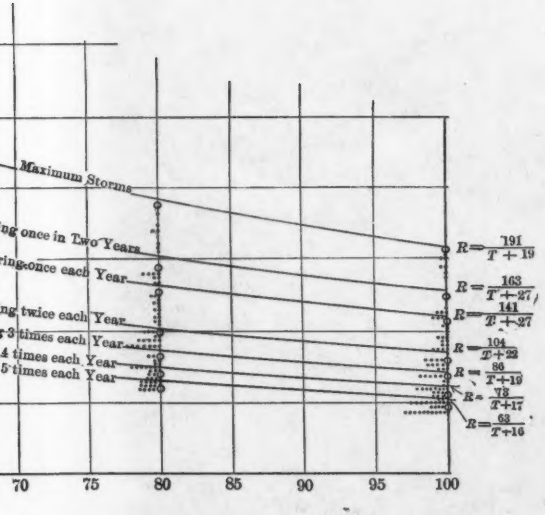
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The line marked "Precipitation in each 5 min." is obtained by putting in the 5-min. column the given accumulation for that period, then subtracting the given 5-min. accumulation from the given 10-min. accumulation and putting the result in the 10-min. column, and so on. The amounts in the line marked "Maximum accumulated precipitation" are: for 5 min., the amount precipitated during the period between 15 and 20 min.; for 10 min., the precipitation during the period between 15 and 25 min.; for 15 min., the precipitation during the period between 10 and 25 min.; and so on, selecting in each case the period, in any part of the storm, that gives the maximum precipitation for that period. In this manner, 162 storms were examined, being all that were reported by the United States Weather Bureau, for the years, and of the intensity, given. Table 1 shows the result of this investigation.

Two other points should be explained, in reference to the table: First, in tabulating the results of any storm which gave a greater rate of precipitation for a longer period than for a shorter one, the greater rate was tabulated for the shorter as well as for the longer period. For instance, in the storm of December 8th, 1890, it will be seen that the maximum rate for 20 min. was 2.25 in., while the maximum rate for 25 min. was 2.28 in. The rate has been tabulated as 2.28 in. in both cases, on the general grounds that if it rained at the rate of 2.28 in. for 25 min., it is reasonable to say that it rained at an equal rate for a less time.

The other point is, that all storms have been extended, from the point of their ending to the limit of time to which the investigation was carried (100 min.). This extension was made on the ground that if a storm gave, say, 0.5 in. of precipitation in 10 min. and then stopped, the effect on a drainage area in which the time of accumulation at the outlet was more than 10 min. would certainly be not less than if the same storm had precipitated 0.5 in. in the accumulation time of the area, whether it were 15 or 100 min.; and the probability is that it would be greater. In Table 1, therefore, the extended rates have been calculated on the total accumulated amounts as though they had been precipitated in the extended times. In order that these extended rates may be distinguished from the actual rates, they have been printed in italics.

In Plate CXIII have been plotted about one hundred of the highest

values for each 5-min. period, as taken from Table 1. At the maximum value, and from there counting downward 9, 18, 36, 54, 72, and 90, t plottings have been made larger than the others. As the number of years examined is 18, these large plottings indicate the rates of maximum storms and those occurring on an average of once in two years, and one, two, three, four, and five times each year. Through these points have been passed, with more or less success, regular curves, the equations for which are noted at the right of Plate CXIII.

The following comparison of Professor Talbot's "Maximum curve for the eastern part of the country," with the maximum curve for Savannah, Ga., as deduced by the writer, is of interest:

Minutes	5	10	15	20	25	30
Talbot $R = \frac{105}{T+15}$	5.25	4.20	3.50	3.00	2.63	2.34
Savannah $R = \frac{191}{T+19}$	7.96	6.59	5.62	4.90	4.34	3.90

Minutes	35	40	45	50	55	60	80	100
Talbot	2.10	1.91	1.75	1.62	1.50	1.40	1.10	0.92
Savannah	3.54	3.24	2.99	2.77	2.59	2.42	1.93	1.60

The comparison of Folwell's curve for "Storms of the second class for the South Atlantic and Gulf States," with the corresponding curve for storms occurring once in two years, as found for Savannah conditions, is also made so that the differences can be readily seen:

Minutes	5	10	15	20	25	30	35
Folwell	5.50	4.25	3.54	3.05	2.68	2.44	2.26
Savannah $R = \frac{163}{T+27}$	5.10	4.41	3.88	3.46	3.14	2.86	2.63

Minutes	40	45	50	55	60
Folwell	2.11	2.00	1.92	1.86	1.80
Savannah	2.44	2.26	2.12	1.99	1.87

As Folwell gives no formula for his curve, the evaluation was made from the curve shown on page 125 of the book previously quoted.

TABLE 1.—RATE OF RAINFALL AT SAVANNAH, GEORGIA (IN INCHES PER HOUR), AS RECORDED BY THE AUTOMATIC RAIN GAUGE OF THE U. S. WEATHER BUREAU, FOR ALL STORMS IN WHICH THE PRECIPITATION AMOUNTED TO 0.25 IN. IN ANY 5 MIN., OR 0.75 IN. IN 1 HOUR, DURING THE YEARS 1889 TO 1906, INCLUSIVE,

NOTE: The figures in italics show the extended rates, after the storm had stopped.

No. of Storm.	Date.	Duration of Periods, in Minutes.													
		5	10	15	20	25	30	35	40	45	50	55	60	80	100
1	June 27, 1889.	3.96	3.84	2.84	2.43	2.09	1.92	1.79	1.70	1.60	1.55	*1.41*	*1.29*	*0.96*	*0.77*
2	June 28, 1889.	2.28	2.04	1.76	1.62	1.44	1.30	1.29	1.22	1.14	*1.03*	*0.93*	*0.86*	*0.65*	*0.52*
3	July 6, 1889.	3.60	2.84	1.88	1.68	1.56	1.38	*1.18*	*1.04*	*0.91*	*0.83*	*0.75*	*0.69*	*0.52*	*0.41*
4	Aug. 6, 1889.	4.56	4.38	4.32	4.17	3.91	3.66	3.34	3.08	2.88	2.59	2.38	2.22	1.71	1.44
5	Aug. 8, 1889.	4.80	4.80	3.80	3.15	2.59	*2.16*	*1.85*	*1.62*	*1.43*	*1.30*	*1.17*	*1.08*	*0.81*	*0.65*
6	Sept. 1, 1889	4.20	3.90	3.80	*2.85*	*2.28*	*1.90*	*1.63*	*1.43*	*1.26*	*1.14*	*1.03*	*0.95*	*0.71*	*0.57*
7	Sept. 6, 1889.	3.60	3.30	2.80	2.52	2.14	1.90	1.72	*1.50*	*1.33*	*1.20*	*1.09*	*1.00*	*0.75*	*0.60*
8	May 3, 1890.	3.00	2.22	2.20	*1.65*	*1.32*	*1.10*	*0.94*	*0.83*	*0.73*	*0.66*	*0.60*	*0.55*	*0.41*	*0.33*
9	June 11, 1890.	3.60	3.00	2.60	2.25	1.92	1.70	1.55	*1.35*	*1.20*	*1.08*	*0.98*	*0.90*	*0.68*	*0.54*
10	June 20, 1890.	2.40	1.74	1.60	1.71	1.49	*1.24*	*1.06*	*0.93*	*0.82*	*0.74*	*0.67*	*0.62*	*0.47*	*0.37*
11	July 1, 1890.	3.00	3.00	2.40	*1.80*	*1.44*	*1.20*	*1.03*	*0.90*	*0.80*	*0.72*	*0.65*	*0.60*	*0.45*	*0.36*
12	July 8, 1890.	4.20	4.20	3.40	2.88	*2.30*	*1.92*	*1.65*	*1.44*	*1.28*	*1.15*	*1.05*	*0.96*	*0.72*	*0.58*
13	July 27, 1890.	3.36	2.88	2.28	1.86	1.56	1.40	1.24	1.11	1.00	0.91	0.91	0.91	0.91	0.79
14	Sept. 1-2, 1890.	2.40	1.62	1.36	1.20	1.13	1.00	0.93	0.93	0.88	0.82	0.77	0.73	0.71	0.63
15	Sept. 2, 1890.	3.00	2.70	2.20	1.86	1.66	1.54	1.44	1.32	1.21	1.13	1.05	0.99	0.91	0.87
16	Sept. 3, 1890.	2.28	1.44	1.08	0.87	0.79	0.77	0.77	*0.67*	*0.60*	*0.54*	*0.49*	*0.45*	*0.34*	*0.27*
17	Sept. 11, 1890.	3.00	2.04	1.64	1.32	*1.06*	*0.88*	*0.76*	*0.66*	*0.59*	*0.53*	*0.48*	*0.44*	*0.33*	*0.26*
18	Sept. 13, 1890.	2.40	2.40	2.00	1.95	*1.56*	*1.30*	*1.11*	*0.98*	*0.86*	*0.78*	*0.71*	*0.65*	*0.49*	*0.39*
19	Sept. 15, 1890.	1.80	1.80	1.56	1.38	1.22	1.10	1.00	0.92	0.85	*0.77*	*0.70*	*0.64*	*0.48*	*0.38*
20	Sept. 22, 1890.	2.40	1.80	1.24	*0.93*	*0.74*	*0.62*	*0.53*	*0.47*	*0.41*	*0.37*	*0.34*	*0.31*	*0.23*	*0.19*
21	Sept. 24, 1890.	2.64	2.40	2.28	2.31	2.16	1.94	1.93	1.93	1.93	1.82	1.61	1.40	1.28	*1.02*
22	Oct. 22, 1890.	4.20	3.60	3.12	2.76	2.38	2.02	*1.73*	*1.52*	*1.34*	*1.21*	*1.10*	*1.01*	*0.76*	*0.61*
23	Dec. 8, 1890.	3.00	2.70	2.52	2.28	2.28	2.06	*1.77*	*1.56*	*1.37*	*1.24*	*1.12*	*1.03*	*0.77*	*0.62*
24	May 27, 1891.	4.20	3.00	2.12	1.68	1.42	*1.18*	*1.01*	*0.88*	*0.78*	*0.71*	*0.64*	*0.59*	*0.44*	*0.35*

TABLE 1.—(*Continued.*)

No. of Storm.	Date.	Duration of Periods, in Minutes.											
		5	10	15	20	25	30	35	40	45	50	55	60	80	100
52	July 31, 1894.	3.60	2.40	2.08	1.71	1.56	1.38	1.27	1.20	1.13	1.02	0.93	0.85	0.64	0.51
53	Aug. 17, 1894.	3.84	3.72	3.60	3.18	2.88	2.58	2.36	2.15	2.00	1.80	1.64	1.50	1.13	0.90
54	Mar. 12, 1895.	2.64	1.62	*1.08*	*0.81*	*0.64*	*0.54*	*0.46*	*0.41*	*0.35*	*0.32*	0.29	0.27	0.20	0.16
55	Apr. 24, 1895.	2.76	1.80	1.60	1.38	1.22	1.08	1.04	1.00	1.00	1.00	1.00	1.00	0.75	0.60
56	May 24, 1895.	2.40	1.80	1.08	1.38	*1.10*	*0.92*	*0.79*	*0.69*	*0.61*	*0.55*	*0.50*	*0.46*	*0.34*	*0.28*
57	June 13, 1895.	3.36	3.00	2.08	2.46	2.11	*1.76*	*1.51*	*1.32*	*1.17*	*1.06*	*0.96*	*0.88*	*0.66*	*0.53*
58	June 16, 1895.	2.40	2.10	2.00	1.98	1.92	1.80	1.73	1.73	1.73	1.63	1.54	1.43	1.25	1.07
59	June 24, 1895.	2.64	2.22	2.00	2.01	1.73	*1.44*	*1.24*	*1.08*	*0.96*	*0.86*	*0.78*	*0.72*	*0.54*	*0.43*
60	June 30, 1895.	2.52	2.10	*1.40*	*1.05*	*0.84*	*0.70*	*0.60*	*0.53*	*0.47*	*0.42*	*0.38*	*0.35*	*0.26*	*0.21*
61	July 7, 1895.	2.76	1.80	1.60	1.35	1.13	0.94	0.80	0.71	0.63	0.56	0.51	0.47	0.35	0.28
62	July 12, 1895.	2.64	1.74	1.36	1.32	1.13	0.94	0.80	0.71	0.63	0.56	0.51	0.47	0.35	0.28
63	July 13, 1895.	6.00	6.00	5.00	5.10	4.32	3.64	3.18	3.02	2.87	2.68	2.43	2.28	1.71	1.37
64	July 25, 1895.	2.88	2.58	2.48	2.46	2.42	2.26	2.11	1.89	1.69	1.54	1.41	1.35	1.25	*1.12*
65	Aug. 3, 1895.	4.20	3.72	3.30	2.88	2.59	2.34	2.24	2.22	2.13	2.06	1.98	1.87	1.50	1.52
66	Aug. 4, 1895.	3.00	2.76	1.92	1.50	*1.20*	*1.00*	*0.86*	*0.75*	*0.67*	*0.60*	*0.55*	*0.50*	*0.38*	*0.30*
67	Aug. 17, 1895.	2.40	1.74	1.28	1.05	*0.84*	*0.70*	*0.60*	*0.53*	*0.47*	*0.42*	*0.38*	*0.35*	*0.26*	*0.21*
68	Aug. 22, 1895.	3.24	2.40	2.20	2.04	1.92	1.64	1.44	1.28	1.14	1.18	1.13	1.13	*0.99*	*0.79*
69	Aug. 22, 1895.	3.12	2.88	2.00	2.04	1.92	1.82	*1.39*	*1.22*	*1.07*	*0.97*	*0.88*	*0.81*	*0.61*	*0.49*
70	Apr. 24, 1896.	3.00	2.82	2.40	2.01	1.75	1.56	1.49	1.31	1.18	1.12	1.07	1.02	0.82	0.75
71	July 7, 1896.	4.20	3.60	3.40	3.00	2.52	2.16	*1.89*	1.67	1.49	1.36	1.24	1.15	0.98	*0.78*
72	Aug. 18, 1896.	3.00	3.00	2.85	2.85	2.40	*2.00*	*1.79*	*1.50*	*1.33*	*1.20*	*1.09*	*1.00*	*0.75*	*0.60*
73	Aug. 26, 1896.	4.20	3.78	3.48	3.21	2.86	2.60	2.44	2.24	2.02	1.88	1.74	1.63	1.22	0.98
74	Feb. 1, 1897.	3.00	1.98	1.52	1.26	1.13	1.08	1.00	0.93	0.84	0.82	0.78	0.76	0.68	0.59
75	Mar. 13, 1897.	4.56	2.64	2.04	1.74	*1.39*	*1.16*	*0.99*	*0.87*	*0.77*	*0.70*	*0.63*	*0.58*	*0.43*	*0.35*
76	Apr. 26, 1897.	3.12	1.56	1.04	0.78	0.62	0.52	0.45	0.39	0.34	0.31	0.28	0.26	0.20	0.16
77	June 15, 1897.	3.84	3.96	3.30	2.88	2.06	2.48	2.30	2.13	1.98	1.86	1.72	1.60	1.20	0.96
78	July 5, 1897.	1.92	1.74	1.68	1.68	1.51	1.48	1.55	1.50	*1.33*	*1.20*	*1.09*	*1.00*	*0.75*	*0.60*

TABLE 1.—(*Continued.*)

No. of Storm.	Date.	Duration of Periods, in Minutes.													
		5	10	15	20	25	30	35	40	45	50	55	60	80	100
25	July 18, 1891.	5.40	5.10	5.00	4.50	4.08	3.64	3.18	*2.78*	*2.46*	*2.22*	*2.02*	*1.85*	*1.39*	*1.11*
26	July 25, 1891.	3.24	2.58	*1.72*	*1.29*	*1.03*	*0.86*	*0.73*	*0.65*	*0.57*	*0.52*	*0.47*	*0.43*	*0.32*	*0.26*
27	July 26, 1891.	3.00	2.52	2.40	2.28	2.04	1.91	1.91	1.77	1.62	1.57	1.53	1.45	*1.08*	*0.87*
28	July 28, 1891.	3.00	2.88	2.64	2.25	2.23	2.02	1.94	1.74	*1.54*	*1.39*	*1.26*	*1.16*	*0.87*	*0.70*
29	Aug. 2.1891.	2.40	1.86	1.52	1.44	*1.15*	*0.96*	*0.82*	*0.72*	*0.64*	*0.58*	*0.52*	*0.48*	*0.36*	*0.29*
30	Aug. 6, 1891.	3.00	2.40	1.88	1.53	*1.22*	*1.02*	*0.87*	*0.77*	*0.68*	*0.61*	*0.56*	*0.51*	*0.38*	*0.31*
31	Aug. 13, 1891.	3.84	2.82	2.48	2.31	2.16	1.94	1.74	1.58	1.50	1.48	1.38	1.30	*0.98*	*0.78*
32	Aug. 23, 1891.	3.60	3.20	3.20	3.00	2.59	2.40	2.11	1.91	1.71	1.57	*1.43*	*1.31*	*0.98*	*0.79*
33	Aug. 28, 1891.	6.00	4.50	4.00	3.60	3.24	2.90	2.53	2.24	2.01	1.84	1.69	1.60	1.60	1.51
34	July 18, 1892.	3.36	3.00	2.80	2.31	1.95	1.95	1.95	1.95	1.77	*1.60*	*1.45*	*1.33*	*1.00*	*0.80*
35	Aug. 10, 1892.	3.96	2.48	2.48	2.10	*1.68*	*1.40*	*1.20*	*1.05*	*0.93*	*0.84*	*0.76*	*0.70*	*0.52*	*0.42*
36	Sept. 12, 1892.	3.00	2.40	2.00	1.71	1.44	1.26	1.12	1.02	0.93	0.90	*0.82*	*0.75*	*0.56*	*0.45*
37	Sept. 19, 1892.	2.40	2.10	1.80	*1.35*	*1.08*	*0.90*	*0.77*	*0.68*	*0.60*	*0.54*	*0.49*	*0.45*	*0.34*	*0.27*
38	Sept. 20, 1892.	1.80	1.72	1.68	1.65	1.51	1.40	1.32	1.25	1.16	1.07	0.97	0.93	0.81	0.75
39	June 7, 1893.	3.12	2.46	2.24	2.10	1.87	1.62	*1.39*	*1.22*	*1.08*	*0.97*	*0.88*	*0.81*	*0.61*	*0.49*
40	July 15, 1893.	2.40	2.28	2.16	2.07	1.92	1.72	1.60	1.53	1.40	1.30	1.20	1.15	1.07	*0.90*
41	Aug. 3. 1893.	3.00	2.70	2.28	2.01	1.68	*1.40*	*1.20*	*1.05*	*0.93*	*0.84*	*0.76*	*0.70*	*0.53*	*0.42*
42	Aug. 14, 1893.	3.00	3.00	2.44	*1.83*	*1.46*	*1.22*	*1.05*	*0.92*	*0.81*	*0.73*	*0.66*	*0.61*	*0.46*	*0.37*
43	Aug. 20, 1893.	3.48	3.24	2.40	*1.80*	*1.44*	*1.20*	*1.03*	*0.90*	*0.80*	*0.72*	*0.65*	*0.60*	*0.45*	*0.36*
44	Aug. 27, 1893.	2.64	2.52	2.20	2.04	1.92	*1.60*	*1.38*	*1.20*	*1.06*	*0.96*	*0.87*	*0.80*	*0.60*	*0.48*
45	Sept. 9, 1893.	3.36	3.00	2.85	2.85	2.66	2.52	2.34	2.27	2.26	2 22	2.18	2.15	1.83	1.57
46	Sept. 13, 1893.	2.40	2.28	1.92	1.86	1.73	1.62	1.53	1.41	1.33	1.22	1.13	1.05	0.83	*0.67*
47	Oct. 3, 1893.	3.60	3.60	2.88	2.34	2.24	2.24	2.03	1.86	1.82	1.72	1.59	1.49	1.33	*1.24*
48	Nov. 27, 1893.	3.00	2.40	2.00	*1.50*	*1.20*	*1.00*	*0.86*	*0.75*	*0.67*	*0.60*	*0.55*	*0.50*	*0.38*	*0.30*
49	June 23, 1894.	3.00	2.70	2.60	2.25	1.87	1.62	1.44	*1.26*	*1.12*	*1.00*	*0.92*	*0.84*	*0.63*	*0.50*
50	July 3, 1894.	2.64	2.10	1.44	*1.08*	*0.86*	*0.72*	*0.62*	*0.54*	*0.48*	*0.43*	*0.39*	*0.36*	*0.27*	*0.22*
51	July 18, 1894.	6.00	5.40	4.80	4.20	3.72	3.20	3.01	2.70	2.46	2.28	*2.07*	*1.90*	*1.43*	*1.14*

TABLE 1.—(*Continued.*)

No. of Storm.	Date.	Duration of Periods, in Minutes.													
		5	10	15	20	25	30	35	40	45	50	55	60	80	100
106	June 17, 1901.	3.60	3.44	3.42	2.76	2.21	1.90	1.86	1.71	1.62	1.55	1.47	1.40	*1.05*	*0.84*
107	July 8, 1901.	3.96	3.18	2.36	2.01	1.92	1.70	1.53	1.38	*1.22*	*1.10*	*1.00*	*0.92*	*0.69*	*0.55*
108	Aug. 7, 1901.	2.40	2.36	2.36	2.19	1.85	*1.54*	*1.32*	*1.15*	*1.02*	*0.92*	*0.84*	*0.77*	*0.58*	*0.46*
109	Aug. 25, 1901.	4.56	3.84	3.24	2.88	2.33	*1.94*	*1.66*	*1.45*	*1.29*	*1.16*	*1.05*	*0.97*	*0.73*	*0.58*
110	Apl. 30, 1902.	1.80	1.68	1.60	1.44	1.44	1.36	1.36	1.36	1.24	1.15	1.11	1.07	0.95	*0.76*
111	May 19, 1902.	2.28	2.16	2.04	1.65	1.34	1.14	1.00	0.90	0.86	0.86	*0.78*	*0.72*	*0.54*	*0.43*
112	July 11–12, 1902.	5.88	4.02	3.96	3.66	3.29	3.19	3.19	3.02	2.85	2.71	2.58	2.42	1.88	*1.51*
113	July 13, 1902.	3.36	3.18	2.94	2.94	2.71	2.46	2.36	2.15	1.92	1.82	1.71	1.61	1.32	*1.06*
114	July 21, 1902.	3.48	2.88	2.12	1.86	1.61	1.36	*1.16*	*1.02*	*0.90*	*0.82*	*0.74*	*0.68*	*0.51*	*0.41*
115	July 27, 1902.	1.80	1.48	1.48	1.38	1.30	1.18	1.07	0.95	*0.82*	*0.74*	*0.68*	*0.63*	*0.47*	*0.37*
116	Aug. 11, 1902.	2.76	2.28	2.04	1.89	1.70	1.64	1.53	1.52	1.48	1.42	1.36	1.30	1.19	*1.05*
117	Aug. 28, 1902.	1.92	1.86	1.68	1.50	1.39	1.34	1.31	1.26	1.25	1.25	1.25	1.24	1.10	*0.88*
118	Sept. 9, 1902.	2.88	2.76	2.64	2.40	2.04	1.76	1.55	*1.35*	*1.20*	*1.08*	*0.98*	*0.90*	*0.68*	*0.54*
119	Dec. 3–4, 1902.	3.84	2.58	1.96	1.86	1.73	1.70	1.62	1.58	1.46	*1.32*	*1.20*	*1.10*	*0.83*	*0.66*
120	June 4, 1903.	3.12	2.76	2.40	2.01	1.63	*1.36*	*1.16*	*1.02*	*0.90*	*0.82*	*0.74*	*0.68*	*0.51*	*0.41*
121	June 8, 1903.	3.00	2.52	2.16	2.01	1.75	*1.46*	*1.25*	*1.09*	*0.97*	*0.88*	*0.80*	*0.73*	*0.55*	*0.44*
122	June 11, 1903.	2.64	2.28	2.00	1.86	1.58	1.52	1.39	1.25	*1.10*	*1.00*	*0.90*	*0.83*	*0.62*	*0.50*
123	June 18, 1903.	2.40	2.10	1.64	1.32	1.20	1.20	1.10	1.01	*0.89*	*0.80*	*0.73*	*0.67*	*0.50*	*0.40*
124	July 9, 1903.	3.72	3.66	3.40	3.30	3.00	2.78	2.63	2.48	2.24	2.15	2.00	1.91	1.58	1.46
125	July 22, 1903.	2.16	1.98	1.96	1.80	1.61	1.40	*1.20*	*1.05*	*0.93*	*0.84*	*0.76*	*0.70*	*0.53*	*0.42*
126	Aug. 15, 1903.	4.44	3.12	3.00	2.28	1.85	1.68	1.63	1.63	1.63	1.63	1.49	1.49	*1.26*	*1.01*
127	Aug. 31, 1903.	3.60	2.40	1.80	1.42	1.42	1.42	1.25	*1.09*	*0.97*	*0.87*	*0.80*	*0.73*	*0.55*	*0.44*
128	Sept. 2, 1903.	6.72	5.64	4.80	4.32	3.91	3.56	3.19	2.80	*2.48*	*2.24*	*2.03*	*1.87*	*1.40*	*1.12*
129	Oct. 16–17, 1903.	2.76	2.16	2.00	2.07	1.85	1.78	*1.53*	*1.33*	*1.18*	*1.07*	*0.97*	*0.89*	*0.66*	*0.53*
130	Nov. 4, 1903.	2.76	2.58	2.16	1.68	1.39	*1.16*	*0.99*	*0.87*	*0.77*	*0.70*	*0.63*	*0.58*	*0.43*	*0.35*
131	June 10, 1904.	2.52	2.34	2.16	1.95	1.82	1.64	1.46	*1.26*	*1.13*	*1.02*	*0.93*	*0.85*	*0.63*	*0.51*
132	July 10, 1904.	2.28	2.28	2.28	2.25	2.18	2.04	1.79	1.62	1.50	1.46	1.37	1.28	*0.96*	*0.77*

TABLE 1.—(*Continued.*)

No. of Storm.	Date.	Duration of Periods, in Minutes.													
		5	10	15	20	25	30	35	40	45	50	55	60	80	100
79	July 11, 1897.	7.80	6.48	5.28	4.29	3.48	*2.90*	*2.49*	*2.17*	*1.93*	*1.74*	*1.58*	*1.45*	*1.09*	*0.87*
80	July 22, 1897.	3.36	3.00	2.80	2.70	2.52	2.34	2.25	2.25	2.18	2.14	1.99	1.84	*1.38*	*1.10*
81	Aug. 14, 1897.	4.56	4.14	3.92	3.81	3.48	3.16	2.89	2.58	2.33	2.14	1.97	1.83	1.39	*1.12*
82	Aug. 15, 1897.	4.32	3.36	2.48	*1.86*	*1.49*	*1.24*	*1.06*	*0.93*	*0.82*	*0.74*	*0.68*	*0.62*	*0.47*	*0.37*
83	June 13, 1898.	2.76	2.46	2.12	1.83	1.68	1.48	1.32	*1.15*	*1.02*	*0.92*	*0.84*	*0.77*	*0.58*	*0.46*
84	June 19, 1898.	3.24	3.18	3.16	2.73	2.35	2.26	2.03	*1.77*	*1.56*	*1.42*	*1.28*	*1.18*	*0.89*	*0.71*
85	July 5–6, 1898.	2.64	2.34	1.96	1.74	1.46	*1.22*	*1.04*	*0.92*	*0.81*	*0.73*	*0.66*	*0.61*	*0.46*	*0.37*
86	July 12–13, 1898.	2.64	2.22	2.04	1.92	1.58	1.36	1.34	*1.17*	*1.03*	*0.94*	*0.85*	*0.78*	*0.59*	*0.47*
87	Aug. 1, 1898.	2.16	1.80	1.76	1.56	1.39	1.34	1.26	*1.10*	*0.97*	*0.88*	*0.80*	*0.73*	*0.55*	*0.44*
88	Aug. 4, 1898.	3.48	2.34	2.00	1.92	1.78	*1.48*	*1.27*	*1.11*	*0.98*	*0.89*	*0.78*	*0.74*	*0.56*	*0.44*
89	Aug. 16–17, 1898.	2.40	2.04	1.64	1.56	*1.25*	*1.04*	*0.89*	*0.78*	*0.69*	*0.62*	*0.57*	*0.52*	*0.39*	*0.31*
90	Aug. 16–17, 1898.	1.92	1.62	1.68	1.53	1.39	1.28	1.27	1.27	1.27	1.26	1.22	1.18	*0.89*	*0.71*
91	Sept. 4, 1898.	4.32	3.68	3.68	3.39	3.07	2.98	2.88	2.66	2.43	2.20	2.00	*1.84*	*1.38*	*1.10*
92	Sept. 8, 1898.	2.40	1.98	1.85	1.85	1.85	1.74	1.67	1.56	1.48	1.37	1.26	1.18	*0.89*	*0.71*
93	Mar. 28, 1899.	4.44	3.06	2.24	1.74	1.42	1.24	1.20	1.12	1.08	1.03	0.99	0.96	*0.72*	*0.58*
94	July 8–9, 1899.	2.64	2.10	2.00	1.42	1.42	1.28	1.20	1.17	1.10	1.08	1.02	0.99	*0.74*	*0.59*
95	Aug. 27–29, 1899.	2.52	2.28	2.08	1.88	1.82	1.70	1.58	1.47	1.38	1.32	1.25	1.19	*0.89*	*0.71*
96	Sept. 17, 1899.	2.28	1.80	1.48	1.41	1.39	1.18	1.15	1.02	1.02	0.95	*0.86*	*0.79*	*0.59*	*0.47*
97	May 18, 1900.	3.36	2.28	1.80	1.56	1.32	1.18	1.07	1.05	0.98	0.92	0.85	0.79	*0.59*	*0.47*
98	May 23, 1900.	1.92	1.68	1.52	1.20	1.04	1.04	1.04	1.04	1.04	0.95	0.87	0.81	*0.61*	*0.49*
99	June 24, 1900.	3.60	3.00	2.76	2.46	2.33	2.08	1.96	1.76	1.57	1.43	*1.29*	*1.19*	*0.89*	*0.71*
100	July 29, 1900.	2.52	2.04	1.64	1.38	1.18	*0.98*	*0.84*	*0.74*	*0.65*	*0.59*	*0.53*	*0.49*	*0.37*	*0.29*
101	Aug. 31, 1900.	2.76	2.52	2.00	1.71	1 49	1.30	1.20	1.10	1.01	*0.91*	*0.83*	*0.76*	*0.57*	*0.46*
102	Sept. 1, 1900.	2.46	2.04	1.80	1.53	1.34	1.20	1.10	*0.96*	*0.85*	*0.77*	*0.70*	*0.64*	*0.48*	*0.38*
103	Sept. 13, 1900.	3.72	3.06	2.68	2.19	*1.75*	*1.46*	*1.26*	*1.09*	*0.97*	*0.88*	*0.80*	*0.73*	*0.55*	*0.44*
104	Oct. 2–3, 1900.	2.64	2.52	2.16	1.71	1.39	1.18	1.16	1.16	1.16	1.16	1.16	1.16	0.96	0.95
105	Nov. 3, 1900.	3.12	2.60	2.60	2.49	2.16	1.92	1.76	1.76	1.60	1.55	1.43	1.34	1.16	*0.93*

TABLE 1.—(*Continued.*)

No. of Storm.	Date.	Duration of Periods, in Minutes.													
		5	10	15	20	25	30	35	40	45	50	55	60	80	100
133	July 24, 1904.	3.00	2.88	2.84	2.76	2.73	2.50	2.33	2.16	2.12	2.12	2.04	1.99	1.73	*1.39*
134	July 28-29, 1904.	3.72	3.36	3.16	*2.37*	*1.90*	*1.58*	*1.36*	*1.18*	*1.05*	*0.95*	*0.86*	*0.79*	*0.59*	*0.47*
135	July 28-29, 1904.	2.88	2.46	2.16	1.98	1.80	1.80	1.80	1.80	1.66	1.58	*1.44*	*1.32*	*0.99*	*0.79*
136	July 28-29, 1904.	4.80	3.96	2.88	2.88	2.71	2.44	2.20	*1.92*	*1.70*	*1.54*	*1.39*	*1.28*	*0.96*	*0.77*
137	July 28-29, 1904.	3.60	3.54	3.44	3.24	3.00	2.80	2.59	2.29	2.04	1.85	1.69	*1.55*	*1.16*	*0.93*
138	Aug. 3, 1904.	4.32	3.78	3.08	*2.31*	*1.85*	*1.54*	*1.32*	*1.16*	*1.02*	*0.92*	*0.84*	*0.77*	*0.58*	*0.46*
139	Aug. 22, 1904.	2.76	2.70	2.48	2.16	2.02	1.86	1.73	1.56	*1.38*	*1.25*	*1.13*	*1.04*	*0.78*	*0.62*
140	Sept. 6, 1904.	2.16	1.98	1.92	1.92	1.82	1.60	1.42	1.32	*1.17*	*1.06*	*0.95*	*0.88*	*0.66*	*0.53*
141	May 7, 1905.	4.20	3.48	2.72	2.64	2.64	2.58	2.39	2.25	2.14	2.04	1.95	1.85	*1.39*	*1.11*
142	May 21, 1905.	2.76	1.80	*1.20*	*0.90*	*0.72*	*0.60*	*0.52*	*0.45*	*0.40*	*0.36*	*0.33*	*0.30*	*0.23*	*0.18*
143	July 5, 1905.	3.12	3.00	2.44	1.98	1.73	*1.44*	*1.23*	*1.08*	*0.95*	*0.86*	*0.78*	*0.72*	*0.54*	*0.43*
144	July 6, 1905.	2.04	1.92	*1.28*	*0.96*	*0.77*	*0.64*	*0.55*	*0.48*	*0.43*	*0 38*	*0.35*	*0.32*	*0.24*	*0.19*
145	July 23, 1905.	3.72	1.98	*1.32*	*0.99*	*0.79*	*0.66*	*0.57*	*0.49*	*0.44*	*0.40*	*0.36*	*0.33*	*0.25*	*0.20*
146	July 25, 1905.	2.64	2.22	2.04	1.89	1.80	*1.50*	*1.29*	*1.13*	*1.00*	*0.90*	*0.82*	*0.75*	*0.56*	*0.45*
147	July 28, 1905.	3.96	3.40	3.40	3.39	3.22	2.82	2.68	*2.34*	*2.07*	*1.87*	*1.70*	*1.56*	*1.17*	*0.94*
148	Aug. 12, 1905.	4.92	3.18	*2.12*	*1.59*	*1.27*	*1.06*	*0.91*	*0.80*	*0.70*	*0.64*	*0.58*	*0.53*	*0.39*	*0.31*
149	Aug. 18, 1905.	4.68	3.90	*2.60*	*1.95*	*1.56*	*1.30*	*1.11*	*0.97*	*0.86*	*0.78*	*0.71*	*0.65*	*0.49*	*0.39*
150	Sept. 13, 1905.	3.00	2.70	2.68	2.61	2.40	*2.00*	*1.72*	*1.50*	*1.33*	*1.20*	*1.09*	*1.00*	*0.75*	*0.60*
151	Sept. 21, 1905.	2.88	2.76	2.72	2.58	2.50	2.18	1.96	*1.71*	*1.51*	*1.37*	*1.24*	*1.14*	*0.86*	*0.68*
152	Oct. 4, 1905.	3.36	2.94	2.68	2.16	1.87	1.66	*1.42*	*1.25*	*1.10*	*1.00*	*0.90*	*0.83*	*0.62*	*0.50*
153	Oct. 26, 1905.	1.80	1.68	1.48	1.38	1.32	1.22	*1.04*	*0.91*	*0.81*	*0.73*	*0.66*	*0.61*	*0.46*	*0.37*
154	Apr. 14, 1906.	4.32	3.48	2.68	2.49	2.18	*1.82*	*1.56*	*1.37*	*1.21*	*1.09*	*0.99*	*0.91*	*0.68*	*0.55*
155	June 27, 1906.	2.16	1.98	1.40	*1.05*	*0.84*	*0.70*	*0.60*	*0.53*	*0.47*	*0.42*	*0.38*	*0.35*	*0.26*	*0.21*
156	July 30, 1906.	1.80	1.62	1.40	*1.05*	*0.84*	*0.70*	*0.60*	*0.53*	*0.47*	*0.42*	*0.38*	*0.35*	*0.26*	*0.21*
157	July 30, 1906.	3.24	2.88	2.44	1.95	*1.56*	*1.30*	*1.11*	*0.97*	*0.86*	*0.78*	*0.71*	*0.65*	*0.49*	*0.39*
158	Aug. 23, 1906.	2.52	2.16	1.64	*1.23*	*0.98*	*0.82*	*0.71*	*0.62*	*0.55*	*0.49*	*0.45*	*0.41*	*0.31*	*0.24*
159	Aug. 27, 1906.	2.64	2.46	2.04	1.98	1.85	1.66	*1.42*	*1.24*	*1.10*	*1.00*	*0.90*	*0.83*	*0.62*	*0.50*
160	Aug. 28, 1906.	3.12	2.58	2.28	2.16	1.78	*1.48*	*1.27*	*1.11*	*0.98*	*0.89*	*0.81*	*0.74*	*0.56*	*0.44*
161	Sept. 5, 1906.	2.64	1.62	1.36	1.23	1.42	1.26	*1.08*	*0.95*	*0.84*	*0.76*	*0.69*	*0.63*	*0.47*	*0.38*
162	Sept. 26, 1906.	2.64	1.80	1.44	*1.08*	*0.86*	*0.72*	*0.62*	*0.54*	*0.48*	*0.43*	*0.39*	*0.36*	*0.27*	*0.21*

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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WATER PURIFICATION AT ST. LOUIS, MO.

Discussion.*

By Messrs. George A. Soper, G. C. Whipple, L. L. Tribus, and L. J. Le Conte.

Mr. Soper. George A. Soper, M. Am. Soc. C. E.—All should feel indebted to Mr. Wall for his description of the method of purifying the public water supply of St. Louis, and particularly for his description of the method of handling the large quantities of chemicals required.

As to the effects of the process, it seems to be too soon to form a final opinion. There have been abundant illustrations elsewhere of the usefulness of chemical precipitation, and of precipitation with iron and lime, but chemicals are generally used as a preliminary to filtration.

It will necessarily be some time before the sanitary value of the St. Louis works can be accurately measured. There is no doubt that the water has been improved, and improved materially, and apparently at a comparatively small cost; but the measure of that improvement depends on facts and figures which are not yet available. The speaker would like to see more analytical and statistical data concerning the effects of operation.

There are, of course, drawbacks to the use of chemicals, in treating a water supply. All these drawbacks are not self-evident. One objection results from the changes sometimes produced in the mineral content of the water. The speaker does not know that there has been any trouble with boilers or distributing pipes in St. Louis, but it is one of the things to look out for.

* Continued from November, 1907, *Proceedings*.

Mr. Soper. Considerable interest attaches to the author's remarks concerning the diminution in typhoid fever which seemed to follow the introduction of the plant. The use of typhoid statistics, in measuring the effect of an improved water supply, has many pitfalls and difficulties, and it would not be strange if the author had fallen into one or more of them. It is, unfortunately, unsafe to rely even on the vital statistics collected in many of the most advanced and best governed American cities, for, in the first place, physicians do not always know typhoid fever when they see it, and, in the second place, they do not always report it when they recognize it.

The speaker would like to know, if convenient to the author, how many cases of other fevers, which might have been typhoid, occurred during the period covered by his typhoid statistics. The statistics seem to be in error, because it appears that there has been a case mortality of from 14 to 25%, while it is probable that not more than 8% of all people attacked by typhoid die of it.

Even if the few statistics given were as accurate as could be desired, they would not of necessity show much of importance concerning the operation of the works. It is not easy to understand how much typhoid, in a city like St. Louis, is due to water. There are usually many other sources of this disease. It seems to be quite possible that, if all the facts were known, it would appear that the water supply of St. Louis has had in the last few years very little to do with the prevalence of typhoid, and that the disease has not increased or diminished to the extent commonly supposed.

There is a final point, which the speaker hesitates to mention, but inasmuch as, before this Society, it will probably be taken in the conservative spirit in which it is intended, and may lead to useful inquiries, it may be referred to briefly. It concerns the composition of the sulphate of iron used. How much iron is present, and how much acid? What is the quality of the lime? The chemicals cannot be pure. No city could afford to pay for pure chemicals, even if they were obtainable. What are the impurities? How much arsenic is there in this sulphate? Some years ago the speaker had occasion to examine specimens of sulphate of aluminum from a good many filter plants, and found arsenic in nearly all of them. It is true that, usually, the arsenic was not present in large quantity, but it was easily discoverable, and in some of the samples it was present in sufficient amount to be of more than passing interest. The arsenic, of course, came from the sulphuric acid used in making the sulphate of aluminum, the sulphuric acid having been produced from pyrites which contained arsenic.

Mr. Whipple. G. C. WHIPPLE, ASSOC. M. AM. SOC. C. E.—There are a number of questions that the speaker would like to ask in regard to this interesting paper, especially as to the details of the method by which the

chemicals are applied to the water. He is more interested, however, in the general principles of the process and in the results, than in the details. This method of purification by chemical precipitation is usually regarded as a preliminary process, to be followed by filtration; but in this case the preliminary process is stretched so as to perform all the work that is done. The results which have been accomplished by this stretching of a preliminary process are of great interest, and no doubt the people of St. Louis appreciate very much the improvement that has been made in the quality of their water supply. Mr. Whipple.

It seems to the speaker, however, that the author takes altogether too roseate a view of the future. For instance, near the close of the paper is found this statement:

"With these basins in service and the improved facilities for uniform treatment afforded by the new coagulating plant, there is no reason to doubt that St. Louis will be supplied with water as agreeable to the eye and as pure and wholesome as is enjoyed by any city in the United States."

This is certainly an exaggeration. The speaker cannot believe that the results of this process are going to be as good as the results which would be obtained by supplementing chemical coagulation with filtration, according to modern methods; and it does not seem to him that the figures presented in the tables bear out the statement just quoted. In the early part of the paper the author speaks of the tap water in St. Louis in 1904 as being clear and sparkling. To translate this into the language used by the chemist would be to say that the water had a turbidity of zero. The tables in the paper show that the turbidity of the water has not always been zero, but often far from it; or rather, they show that the suspended matter has not been zero, for it will be noticed that figures for the turbidity of the tap water are not given at all. They are simply given for the water before treatment. The speaker hopes that, in his closing discussion, the author will supply this deficiency.

Of the few analyses given, some are monthly averages, and others were taken a week apart. Now, it is a well-known fact that a monthly average often does not tell what the condition of the water has been from day to day. The figures for a month may be fairly low and satisfactory, and yet there may have been days during that month when the water was not satisfactory. This the speaker knows from experience, and there is no reason to believe that it is not true of the St. Louis water. That the product of such a plant as this would be irregular, would naturally be expected, for while the application of the chemicals may be under control, the natural physical and meteorological conditions which affect the sedimentation are not subject to control.

The speaker had the pleasure of visiting the St. Louis plant, during the early part of the work, at a time when it was not working as

Mr. Whipple. well as it evidently has been lately, but he then saw an illustration of its irregularity. For the month of June, 1904, the amount of suspended matter in the effluent is given in Table 1 as 39 parts per million, and yet on the day when the speaker was there the turbidity of the water leaving the settling basins was 400. Therefore, it seems to the speaker that the figures given may be, to a certain extent, a little misleading, and may give an idea that the water is clearer than it sometimes really is. Countenance is lent to this view by reports which have come from persons who have visited the city and who, while they remark that the quality of the water has been very greatly improved, speak of its occasional turbidity.

The speaker agrees with Dr. Soper that the data are hardly sufficient to give the water supply an absolutely clean bill of health, and that they do not show what may be the final results of this treatment, from a sanitary point of view. The figures, admitting their accuracy, do show a great reduction in the typhoid fever death-rate, but if one were to follow the typhoid fever records back for a number of years before those tabulated, he would find that about ten years ago the typhoid fever death-rates were nearly as low as they have been during the last year or two, and that this was during the time when the city was depending on plain sedimentation, without the use of chemicals, for the purification of the supply.

Here it should be noticed that the author refers to the efficiency of the old sedimentation process as being "from 10 to 80 per cent." Now, the report of the commission which studied the water supply in 1904 gave the efficiency of the settling basins as "from 75 to 94%," and gave the average efficiency as 85%, while, if the speaker recollects correctly, later observations made by Mr. Fladd showed the efficiency of the sedimentation process without chemicals to be more than 90%, a figure which comes closer to the figures given for the chemical process in the paper.

The speaker mentions these matters because it seems to him that this paper might be made of very much greater value, and certainly much more convincing, by giving more detailed information regarding the quality of the treated water. Some of the omissions were doubtless accidental, for the author speaks in one place of tables giving the results of turbidity, and in another place of tables giving the results of tests for *B. Coli* and other tests, which data are not found in the places mentioned.

One other point might be mentioned, namely, the effect which the use of these chemicals may have on the mineral quality of the water. It is well known that, where lime is used, the reaction is not instantaneous, and there are apt to occur what are known as "after deposits" of calcium carbonate, etc. These deposits may take place after the water has left the settling basins. The speaker once visited a city where there were considerable deposits of lime on the inner

surfaces of the service pipes and on the working parts of meters. These deposits were not very large, but were quite noticeable. There is no reason to doubt that in time this will happen in St. Louis. Mr. Whipple.

The question of the quality of the ferrous sulphate used has been raised by Dr. Soper. This is an important matter, for the chemical may conceivably contain substances which may be detrimental to the pumps through which the water passes.

In conclusion, the speaker wishes to congratulate the City of St. Louis for what its engineers have done. They deserve praise for the energetic manner in which they have taken hold of the problem. He hopes, however, that the city will not content itself with a half-way process, but will use as much energy in securing a complete process of purification as it has used in developing this preliminary process of chemical precipitation.

L. L. TRIBUS, M. AM. SOC. C. E.—The speaker has read this paper with considerable interest, and desires to call attention to one thing in particular—and a very commendable matter, at that. While St. Louis was discussing, and had been considering for years, the question of an improved water supply, with experts from all over the country, Boards of Trade, Chambers of Commerce, citizens, etc., yet no one seemed to be able to suggest any really practical method of doing the work, until the gentlemen mentioned in this paper, having to meet the situation, designed a plant which has done the work, and has given water of vastly better quality than that with which the city had ever been supplied. That is a true engineering feat, and deserves high praise. Mr. Tribus.

It is very probable—and the speaker does not disagree with either Mr. Soper or Mr. Whipple—that better results can be secured by carrying the process forward, by filtering the water after it passes through the sedimentation tanks, or by greater chemical refinement; but the main point stands out that the engineers met a difficult situation, and built a practicable plant in a short time, and at a comparatively small cost.

L. J. LE CONTE, M. AM. SOC. C. E. (by letter).—This problem has engaged the closest attention of engineers for many years, and the general conclusion has been that sedimentation—followed by coagulation and filtration—was the proper solution. The expense of such purification approximates from $15 to $17 per million gallons. Mr. Le Conte.

The author's recent experience at St. Louis, however, seems to show that, for all practical purposes, the whole operation can be performed successfully by coagulation, followed by prolonged sedimentation, thus apparently shutting out entirely the expensive necessity for filtration. According to his experience, the water can be purified for $5 per million gallons. Of course, all have understood, heretofore, that it is physically possible to accomplish the entire operation of

Mr. Le Conte.

clarification by coagulation and subsidence; but it has always been maintained, with much force and judgment, that it was unwise to do so, on a large scale, because a considerable portion of the coarser sediment could first be removed more cheaply and successfully by plain subsidence, and, most important of all, that the last traces of clay particles could be more completely removed by filtration than by a prolonged settling.

Furthermore, engineers have generally held that good reliable sanitary requirements, as to bacterial efficiency, could best be accomplished and properly maintained by filtration. The author now states that the same bacterial efficiency can be had by simple coagulation and prolonged subsidence, and that the result is accomplished at one-third the cost. This is a most important fact. It would appear, however, by reference to the various tables submitted, that, in point of fact, the clarification is not by any means such as would be desired by a fastidious community. The average "color" is given as 10 to 12, whereas the effluent from good filters generally shows 0 to 5. That is to say, it is more than four times as cloudy as good filtered water.

Table 4 shows that in November, 1906, and in January and February, 1907, the bacterial efficiency was below standard, and that in March, 1907, for the first time in three years' operations, it was above standard. That is to say, from a sanitary point of view, the water delivered to consumers was unsafe most of the time except during the last month of operations.

It would be interesting to know whether or not the maximum quantity of sulphate of iron (3.75 gr. per gal.) and the maximum quantity of lime (11.0 gr. per gal.) used during the third year of operation were actually consumed during March, 1907, when the bacterial efficiency was satisfactory.

The writer is greatly impressed by the good results in Table 2, showing the reduction in the typhoid death-rate due, undoubtedly, to water purification. This feature, above all others, appeals to one's sense of humanity. The results stand out in strong contrast with the late experience in Washington, D. C., where, apparently, the filters failed to lower the typhoid death-rate, as was reasonably expected.

There is no doubt, however, that the bacterial efficiency attained in the St. Louis experiments is practically all that could be desired, from a sanitary point of view, and the expense incurred, namely, $4.62 per million gallons, is only about one-third of that of good filtered Mississippi River water.

The whole question, then, turns upon the degree of clarification necessary or desirable in each case. Each city is now at liberty to decide for itself according to its financial ability, and later, perhaps, when better able to stand the extra burden, may introduce filtration. This will prove to be particularly good news to many western cities now supplied with muddy river waters.

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PAPERS AND DISCUSSIONS.

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THE BRACING OF TRENCHES AND TUNNELS, WITH PRACTICAL FORMULAS FOR EARTH PRESSURES.

Discussion.*

By Messrs. H. P. Moran, E. W. Stern, G. L. Christian, V. H. Hewes, E. P. Goodrich, J. F. O'Rourke, O. F. Nichols, and W. H. Gahagan.

H. P. Moran, Esq. (by letter).—In the construction of the Brooklyn Subway, with which the writer is connected, it was necessary to excavate a trench averaging 30 ft. deep and 5 000 ft. long. The bank was composed of sand and gravel with some few boulders. The bracing, designed by Mr. Meem, had the larger braces at the top and smaller braces when approaching the bottom. In no single instance has any failure of the lower and lighter braces been observed. Many instances of bending of the upper rangers, however, have been noticed. Mr. Moran.

In reconstructing the Hanson Place sewer, the trench excavated was 45 ft. deep, and there were seven sets of rangers; the larger ones being at the top. It was noticed that the top rangers had bowed at various places, the lower four rangers remaining perfectly straight. Great care was always taken to prevent any movement of the bank during the process of bracing.

It seems obvious to the writer that, under similar conditions of fill, the greatest pressure will always come at the top.

A permanent structure, such as a retaining wall, should be designed to withstand the maximum thrust of the earth. One should determine: First, the total pressure; second, its line of action; and third, its point of application. Obtaining the total thrust, it is evident that as the lever arm is increased, the overturning moment becomes greater.

* Continued from November, 1907, *Proceedings*.

Mr. Moran. If the point of application be taken as two-thirds of the distance from the bottom, the maximum overturning moment will be obtained.

Comparing the thickness of a rectangular wall, designed, first according to Mr. Meem's method, and second, according to current practice as represented by Trautwine, it is found that, for a masonry wall, the thickness in the first case will be 46% of the height, no allowance being made for wall friction; in the second case it will be 35% of the height.

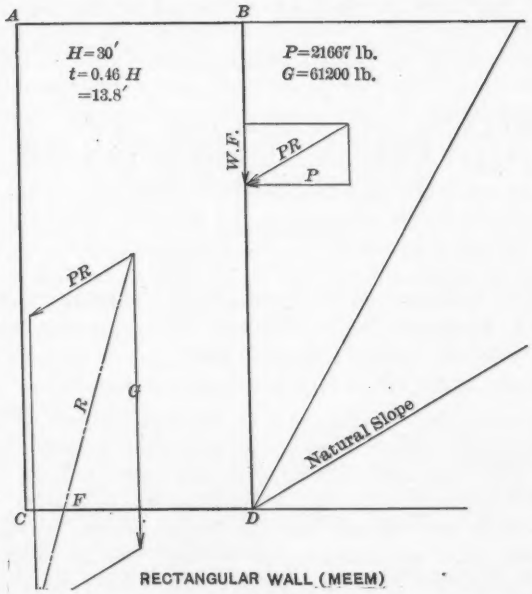


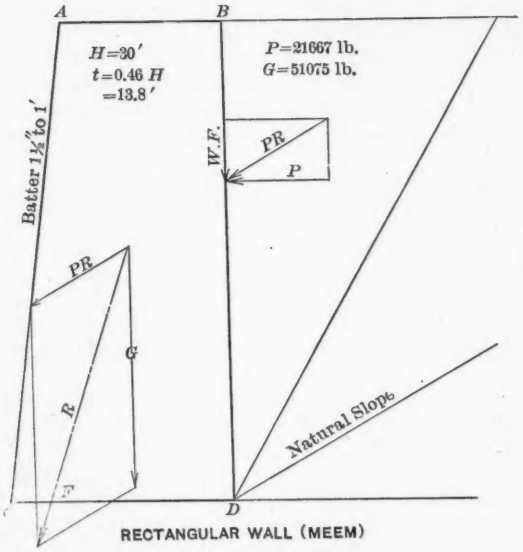
FIG. 45.

Fig. 45 shows graphically a wall designed according to Mr. Meem's theory, with allowance made for wall friction. Fig. 46 shows the same wall with a batter of 1½ in. per ft. Fig. 47 shows a wall having a thickness of 35% of the height (current practice), checked graphically by the same method. In Fig. 47 the resultant passes outside of the toe, indicating that the stability of the wall is questionable, and that excessive pressure would come upon the toe of the wall.

The numerous failures of retaining walls, 90% of which are supposedly due to improper foundations, can be readily explained when considered in the light of Mr. Meem's theories.

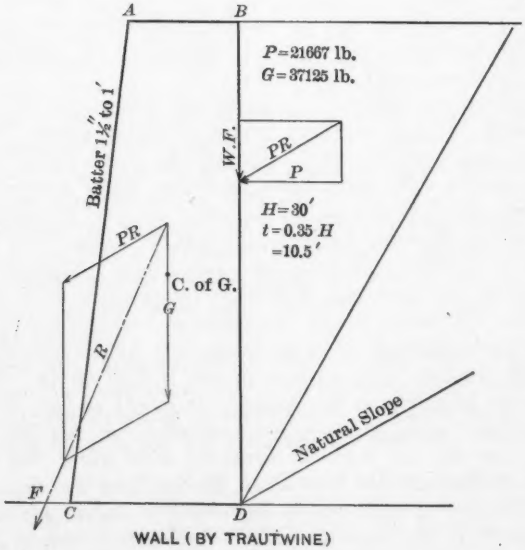
A retaining wall with buttresses presents a different problem—one analogous to that of a sheeted trench. Here the buttresses correspond to the braces, and the wall to the rangers. The wall, therefore, can be designed as a beam, in horizontal sections, to resist sliding and shearing. The overturning force is resisted by the buttresses.

Mr. Moran.



RECTANGULAR WALL (MEEM)

FIG. 46.



WALL (BY TRAUTWINE)

FIG. 47.

Mr. Moran. The pressure varying as the square of the height, and the point of application being two-thirds up from the bottom, gives a wall, triangular in section, having the thickest part at the top and diminishing to zero at the bottom. Practically, it need not be so, and an average thickness could be taken, on the ground that the earth will not only arch itself vertically, but also horizontally, having its springing line at each buttress.

In the case of a reinforced concrete wall with buttresses, the increased strength required at the top could be easily obtained by spacing the horizontal reinforcements closer at the top, and increasing the spacing when approaching the bottom.

A reinforced wall with counterforts tied securely presents a similar problem, where the wall itself can be considered as a beam. As before, the spacing of the horizontal rods should increase as the bottom is approached.

From an analysis of the foregoing examples, the writer concludes that the total force acting cannot be determined by Coulomb's wedge of maximum thrust. This is based primarily upon the assumption that the surface of rupture is a plane. He considers that the surface of rupture is curved, probably parabolic in outline. Using this assumption as a working basis, the total pressure acting two-thirds up from the bottom will be less than the amount obtained by Mr. Meem's straight-line formulas.

Mr. Stern. EUGENE W. STERN, M. AM. SOC. C. E.—The practical experiences recounted by Mr. Meem are extremely interesting and valuable, but the formulas advanced by him do not appeal to the speaker, who still has faith in Coulomb and Weyrauch.

Mr. Meem's conclusions are based on experience in excavating and tunneling through a sandy material under almost ideal conditions. The street paving would prevent the earth below it from becoming saturated with rain water, and the small amount of water which might get through would be very quickly dispersed through the sandy soil, and would be just sufficient to "temper" it nicely.

Altogether different experiences have been obtained in going through a clay or loam soil, which would tend to hold and absorb water. A dry clay bank would stand almost vertically, and if excavations were made through it in perfectly dry weather, such as might obtain in the western arid portions of the United States, where practically no rain falls during the summer, it might be safe to carry out deep excavations with practically no sheeting or bracing whatever. But, as soon as the soil becomes saturated with water, the conditions are entirely different, and instead of its holding an almost vertical face in excavation, it will assume an angle of repose sometimes considerably less than 30 degrees. Now, the surface water cannot get into the soil all at once; it will have to work in gradually, the top

layers becoming saturated first. The pressure on the bracing, therefore, would be greater at the top than at the bottom at first, but, this seepage continuing, it would be found later that at the bottom the pressure was very much greater than at the top. Recently, the speaker had a case which illustrates this point admirably. An excavation for a trench was made in clay soil in dry weather, and the sides were almost vertical. As a precautionary measure, sheeting was put in, with cross-braces. Owing to the negligence of the contractor, only one line of these braces was put in, about half way up from the bottom. A heavy rain fell during the night, and the sheeting was pushed close together at the bottom and out at the top, showing very clearly that the pressure at the bottom was greater than at the top. Mr. Stern.

Another experience by the speaker was in connection with the abutment of a bridge which he was called upon to reconstruct. This abutment, supporting a fill of about 20 ft., was built in the summer, in dry weather, and the filling, consisting of clay loam, was completed also during dry weather. The abutment held up perfectly until the following spring, and then, the clay bank having been saturated with water, and no adequate provision having been made to withdraw this from behind the abutment, it bulged at about one-third of its height above the bottom, showing that the pressure at this point was greatest. This experience is not in accord with the author's formula.

The speaker, also, cannot agree with the theory advanced by Mr. Meem as to the pressure above the roofs of tunnels. He states that the less the angle of repose, the less the pressure will be upon the roof of the tunnel, so that a material like very fine sand, of which the angle of repose is, say, 20°, would cause small pressure, and a material in which the angle of repose is much greater, clay and loam soil, for instance, would cause a greater pressure. If, for the sake of argument, the material had no angle of repose whatever, or practically none—approximating then the condition of a fluid, the molecules of which are frictionless or nearly so—there would be still less pressure on the roof of a tunnel, according to Mr. Meem; with which contention the speaker cannot agree, as this is exactly the opposite of the facts. In the latter case, the pressure is the greatest that can possibly be obtained.

The late Sir Benjamin Baker, Hon. M. Am. Soc. C. E., in a paper, read before the Institution of Civil Engineers many years ago, on the "Actual Lateral Pressure of Earthwork," mentions an interesting case in driving a heading for the Metropolitan Railway. He says:

"The ground consisted of sand and ballast, heavily charged with water, overlying the clay through which the heading was driven, at a depth of 44 feet from the surface. After the heading had been completed some months, the clay became softened to the consistency of putty by the water which filtered through the numerous fissures, and

Mr. Stern. the full weight of the ground took effect upon the settings. Both caps and side trees showed signs of severe stress throughout the entire length of the heading."

This is an interesting example of a condition in which, at the start of the work, the angle of repose of the material being great, the pressure on the roof and sides of the tunnel was not large, but, as soon as the soil became saturated with water, and the angle of repose consequently became very much less than it was originally, the pressure increased enormously.

The speaker believes that the earth over the roof of a tunnel acts as an arch. The greater the angle of repose the material has, the more readily the earth arches, and the greater its strength. The less the angle of repose, the less readily it arches, and the less its strength.

In connection with earth pressures, it is rash to draw any broad conclusions from special experiences, for the reason that the conditions of the soil may vary, and the seepage of water has such an extremely important effect that great variations in pressures may result from these causes. A homogeneous clay in which there is no sand whatever will act differently from one in which there are pockets of sand, or which has gravel or sand overlying it, and entirely different from sand alone, or sand and gravel, and these materials when saturated with water will again act differently. Practical formulas to suit all these conditions would be an impossibility.

The observations of Mr. Meem as to pressures against braces, deduced from his own work, are no doubt correct, but these do not prove that the theories of Weyrauch and Coulomb are wrong. Theory, to be applied properly to a particular case in practice, must take into account all the conditions. Now then, what are the unknown elements in earth pressure?

Eliminating the question of water pressure in the soil, for the sake of argument, and having given the height of the bank, the only point that is uncertain is the angle of repose, and unless the angle of repose is known absolutely, of course, theory and practice cannot be made to agree.

The error most commonly made in applying theory to practice is the assumption that the angle of repose remains constant, no matter what the depth; this, of course, is not tenable. There is no reason why it should be constant, and every reason why it should not be.

In soil that has stood for ages in its original condition, the lower layers will be very much more compacted than the upper ones, by reason of the pressure of the earth above. If excavation is carried deep enough, it is found that the earth is almost in the condition of rock, it is so compactly consolidated. By applying sufficient pressure to a sample of earth, say in a hydrostatic press, it would be possible to make it almost as firm as soft rock.

Mr. Stern.

The angle of repose, therefore, would increase with the depth below the surface in some proportion as the compactness of the soil increased. This condition would apply, not only to clay and loam, but also to sand, when not under the water line.

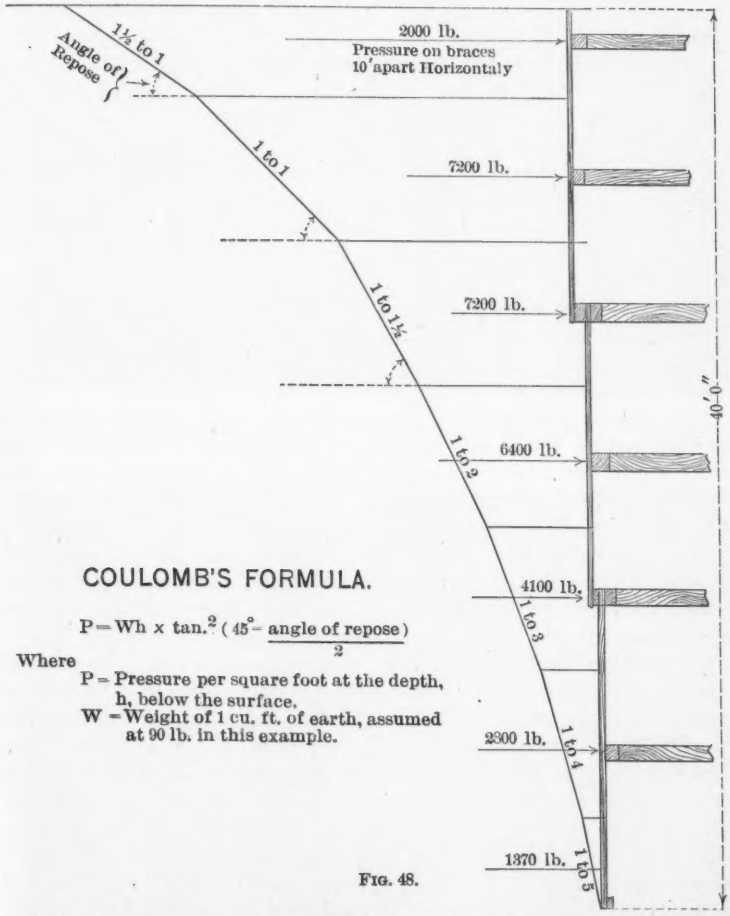


FIG. 48.

Take the case of an excavation through coarse sandy soil in which there is a very small quantity of loam (this is almost always the case). The soil below the surface is usually damp. At the surface, the angle of repose may be 1½ horizontal to 1 vertical. At a depth of 40 ft. below the surface, it may be 1 horizontal to 5 vertical. In clay soil it may be 1 horizontal to 3 vertical near the surface, if dry, and 3 horizontal to 1 vertical if wet, and 20 ft. below, 1 horizontal to 6 or 8 vertical.

Mr. Stern. Now, if the horizontal pressures are computed by Coulomb's theory, on this basis, for the same trench that Mr. Meem has given in his example, Fig. 7, the angle of repose varying gradually from 1½ horizontal to 1 vertical at the surface to 1 horizontal to 5 vertical at 40 ft. below, the pressures on the braces are found to be as shown in Fig. 48.

These pressures, with the exception of that in the top brace, which is less, agree so closely with those given by Mr. Meem that his practical observations do not prove that Coulomb's and Weyrauch's theories are wrong.

The question now arises: Of what practical use are the formulas advanced by the author? Are they sufficiently correct to be used generally? The speaker thinks not. In his opinion, they are of limited application, and—most important of all—the principles enunciated are radically wrong.

Mr. Christian. G. L. CHRISTIAN, M. AM. SOC. C. E.—Mr. Meem is to be congratulated on his paper, relating to a subject upon which little is written. He has evidently given it much thought, guided by his valuable practical experience.

The speaker has in mind two retaining walls (neither of which was designed by engineers) varying in height from 5 to 15 ft. They were observed for more than twenty years, and, in that time, gradually failed in places, by bulging, usually at one-third the height, although occasionally the bulge appeared at one-half the height. The bulging in any particular place was always very slow, and was not sufficient to be noticeable unless several years had elapsed between observations. In the course of time, the parts of the wall where bulging had occurred collapsed.

The speaker once had occasion to place some extra braces across a trench, about 20 ft. wide and of the same depth, in a somewhat clayey soil, and instructed that they be placed pretty well toward the bottom. This did not agree with the ideas of the superintendent for the contractor, who claimed that the greatest pressure was near the top. This was a theory which the speaker had never heard advanced before, and did not believe in then, nor does he now; but he had a good deal of faith in the practical ability of the contractor's representative, and as it was very important that the banks be held rigidly in place, the safe course was adopted of putting in the additional timbers near the top as well as near the bottom.

The speaker does not agree with Mr. Meem's theory that the deeper the trench the lighter should be the lower bracing, although possibly that might be so, provided the trench is sheeted well and there are absolutely no voids behind it. Under those conditions, the author's argument is probably valid, but fails immediately on the appearance of voids, or very soon thereafter.



FIG. 1.—WEST HEADING, MORRIS AVENUE, WEBSTER AVENUE STORM RELIEF SEWER, BRONX BOROUGH, NEW YORK CITY.



FIG. 2.—LOOKING EAST FROM WEST HEADING, MORRIS AVENUE, WEBSTER AVENUE STORM RELIEF SEWER.

Mr. Christian.

The question resolves itself into whether or not it is practical to excavate in any soil and not leave voids, or opportunities for voids to occur behind the sheeting. The speaker thinks it is not.

It would seem that the sheeting on each side of a trench is subjected to the same thrusts as those on a retaining wall in the same position; therefore, as it is necessary to make the wall thicker at the bottom, it follows that the bracing should be designed to withstand the same pressures, and, therefore, must be heavier at the bottom than at the top.

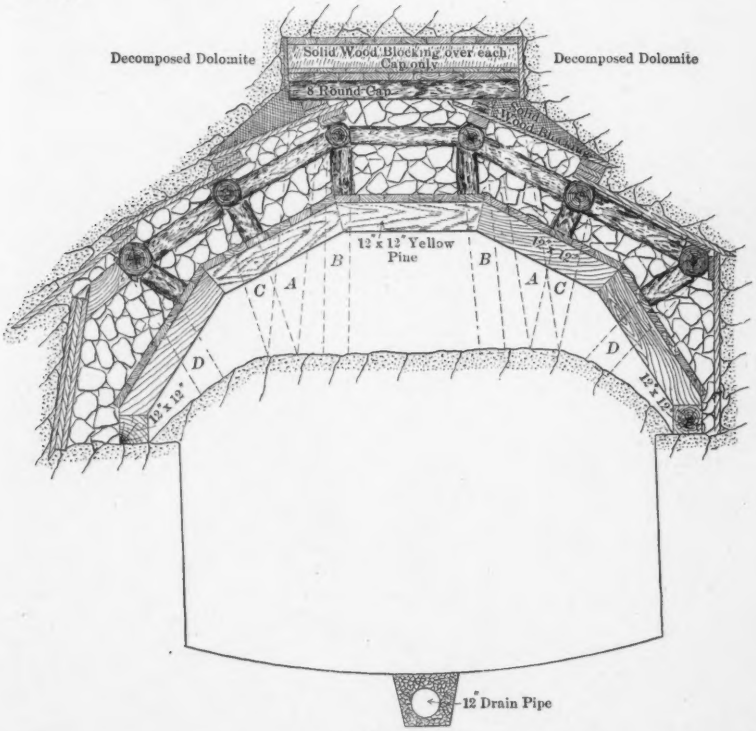


FIG. 49.

In the Borough of The Bronx, New York City, the Webster Avenue Storm Relief Tunnel Sewer is now being driven. Much of the tunnel work passes through a very much decomposed dolomite rock resembling clay. In such places the tunnel has been driven and timbered by the crown-bar method referred to by the author. In this work, a top heading was first driven, as shown by Fig. 1, Plate CXIV. The cap and legs are shown in Fig. 49, the latter by the dotted lines, *A*.

Fig. 49 is an actual cross-section taken on this work. The two

Mr. Christian. center crown-bars are placed in position and held up by the posts, *B*, and then blocking and wedging are driven between the crown-bars and the caps, after which the legs, *A*, are removed. Transverse lagging is next driven above the crown-bars, as shown, after which the next two bars are put in position and held up by the posts, *C*. Transverse lagging is then driven above these bars in the same manner as before, the excavation underneath proceeding meanwhile, after which the two remaining bars are placed in position and held by the posts, *D*. The sides are then lagged; excavation is made for the wall-plates, which are then set to line and grade; and then the segmental arch is placed in position and blocked tightly against the crown-bars, the posts, *B*, *C*, and *D*, being taken out as the work advances.

A good example of this work is shown by Fig. 2, Plate CXIV. In the background may be seen the completed segmental arches, while in the foreground is shown much of the advance timbering just described, *i. e.*, the crown-bars above and their supports, the posts, *B*, showing on the left, and *B*, *C*, and the bottom of *D* on the right.

The bench is next excavated, and then the wall-plates are underpinned, where necessary, after which the work looks like that shown in Plate CXV.

Mr. Hewes. V. H. Hewes, M. Am. Soc. C. E.—The speaker has become greatly interested in the several points brought out in the discussion, and would call attention to the general practice of miners in timbering. After having placed the timbers, the miners proceed to wedge them up so thoroughly that they fairly ring when struck with a hammer. By striking them in this way, they test them to see if the work has been properly done. Thoroughness in wedging is of the greatest importance, for, if there should be any slackness in the timbering, it would allow a movement to take place in the supported material. Should any movement occur, enormous pressure would be developed, often so great that, even if solid cribbing were placed in the workings, the timber would be crushed down.

Several years ago the speaker visited an old Mexican coal mine, then being worked by the fuel department of an American railroad. The timber in the rooms had been removed and the pillars robbed. This brought on what was termed a crush, or squeeze, and no amount of timbering could be placed in the workings to stop it. The only recourse was to run new entries, leaving a considerable body of coal between the workings and the new entry; even then, there was evidence of the movement by the cracking sound given out along the entry.

Evidence of the great pressure exerted by a mass of material which has been disturbed is often shown by the caving in of a mine. The speaker had occasion to go to the 200-ft. level of a mine, where a cave had taken place. The ore was soft hematite. In driving into the



WEBSTER AVENUE STORM RELIEF SEWER, BRONX BOROUGH, NEW YORK CITY.

broken ore at this level it had become so solid and compact that it was impossible to tell which was "unbroken ground" except by following the track rails, which were still in place. It was necessary for the miners to shoot it, in the same way as they would virgin ground. Mr. Hewes.

In an open trench or excavation, if not timbered, the ground in most cases starts to move at or near the surface, and fills up the trench, while that near the bottom may never move. The ground at the top has nothing to hold it in place and prevent its movement, while that at the greater depth is held in place by the material above it. To prevent any movement taking place, timbering is used; and Mr. Meem's experience, that the greatest pressure comes nearer the top of the trench, would not hold when any movement takes place at greater depth, for, in such cases, which often happen, much heavier timbering is required at the bottom than near the top.

E. P. Goodrich, M. Am. Soc. C. E.—This paper should be given much credit, but, at the same time, it is open to considerable adverse criticism. The author presents a number of exceedingly interesting and instructive examples illustrating actual practice in the bracing of trenches and tunnels, but his theories seem to be open to grave question both from theoretical and experimental standpoints. Mr. Goodrich

It is a well-known fact that freshly cut masses of earth of certain kinds will stand for considerable periods with very steep slopes, but, in most cases, it may prove exceedingly dangerous to take advantage of this phenomenon, in an effort to reduce the size and quantity of timbering used to brace those banks. Where the earth is contained in a street, between cellar walls carried to fair depths, and is of a naturally porous nature, some allowance may be made without much risk; but, where work is carried along a side hill, for instance, in a clayey soil, a similar procedure might result in serious damage and loss. Consequently, it is the speaker's opinion that the author's several ideas and recommendations should be adopted only where conditions make them manifestly applicable, as approved by experienced engineers, and that they should not in any wise be considered as of general application.

In a few instances, in the speaker's experience, he has encountered earth pressures which were evidently greater near the ground surface than at lower levels. On the other hand, the opposite condition has been observed in a considerably greater number of cases, and numerous experiments of a very careful nature have shown the close agreement between fact and theory in this regard. These seemingly contradictory observations may be partly explained as follows:

When sheeting is driven along the side of a trench, the earth behind the sheeting is more or less loosened and otherwise disturbed; movements of greater or less magnitude may take place, in the form of slips, sprawling or crawling; cracks or voids may be formed, allow-

Mr. Goodrich.

ing further movements to take place, etc. Such action may be very slow in culminating, but is almost sure to happen with lapse of time and variations in humidity. Furthermore, it is an observed fact that when large breaks occur, they are likely to take place along a curved surface, such as shown diagrammatically in Fig. 50. This fact is recognized by several authors of earth-pressure theories, and is the basis of the theory presented in the discussion of this paper by Mr. Haines.

Now, in dry soils, when the toe is prevented from sliding, a mass may crack away from the bank and tilt over at the top, turning about the toe, as shown in an exaggerated manner in Fig. 51. Such action would account for the cracks often found at various distances back from the edge of an excavation, though they may also be produced by local settlement, or by several other causes. It would also throw the heaviest stresses into the upper braces, and would tend to confirm the author's theories. On the other hand, if the toe is not so well fixed, and if the soil is more humid, a slip is likely to take place, as shown in an exaggerated manner in Fig. 52. This is the usual condition, and, obviously, would produce maximum stresses in the lower braces.

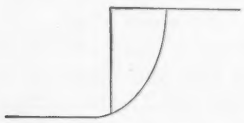


FIG. 50.



FIG. 51.



FIG. 52.

Again, many soils will "crawl" or appear to flow, acting like a viscous material. For such conditions, the theory advanced by the author would seem untenable, because both vertical and lateral pressures are then proportional to the depth. Damp clay is such a material, while dry clay may possess considerable cohesive strength. The speaker has seen tunnels driven through clay, and these have stood, for days at a time, for considerable distances and heights, without support and without change. In other cases, he has known the sides of similar tunnels to stand without material change of form, but to move bodily inward with such force as to crush to pulp the ends of heavy timbers. In another case, he was called to examine a tunnel and the nearby buildings, where the sides of the brick tunnel lining had been crushed inward, allowing a movement of the soil which endangered the foundations of even relatively distant buildings. The humidity of the soil had been greatly increased by the bursting of a sewer, thus producing unexpected conditions of stress which were quite extraordinary, but evidently also really possible. The two last

mentioned cases are explainable only by such theories as developed by Rankine; and those of the author would prove entirely inadequate. The latter must evidently be qualified most carefully as to the period of time which can elapse, the conditions of humidity, the kind of soil, etc. Mr. Goodrich.

This qualification is actually made by the author in several instances, thus showing the pertinence of the speaker's criticism.

On page 607,* the author says, "where the trench does not have to stand too long." On page 617,* he advocates maintaining "some sort of a bench at or near" the toe of the bank inside the sheeting. This seems to be inconsistent, when viewed in the light of his statement on page 604,* that "the lower part of a trench may be left unsheeted." On page 611,* he qualifies the application of his theories to clays, by saying that they "frequently develop pressures by squeezing or sliding horizontally, for which it is difficult to provide." On page 600,* however, he has endeavored:

"to develop a practical basis in connection with which it will be possible at all times to effect an approximate reconciliation between the actual conditions of stability of earth and the theoretical formulas or resultants arising therefrom."

The qualifying statements introduced by the author seem to place his theory, also, among those which he condemns as not being able "to reconcile the theoretical with the practical conditions."

Again, on page 612,* Mr. Meem speaks of a "frictionless material" having "an angle of repose" greater than zero. This is an obvious inconsistency, and when a zero angle is properly applied to the condition being discussed by the author, his seemingly logical deduction as to the weight coming upon the top of a tunnel would lead to an infinite value, which could not possibly obtain.

The author's deduction, on page 614,* that earth will arch around a circular manhole with the same perfection at "indefinite depths," as close to the surface, does not seem compatible with the physical conditions which must exist in an arch formed in a granular mass. It is true that such materials will form effective arches over considerable spans, with certain sizes of grains and conditions of humidity, friction, or cohesion. For example, wheat will often arch completely across the ordinary elevator bins, and the effects on each other of loaded piles driven in soft ground show analogous action over distances of 20 ft. or more. Most earth-pressure experiments also confirm these observations, but to push, as far as the author has done, any deductions as to the effects of arch action, seems like exceeding the limits set by facts and sound theories. Because various large voids may have existed for long periods is not deemed a sufficient premise for all the conclusions reached. On page 613,* the author does not give any definite

**Proceedings*, Am. Soc. C. E., for August, 1907.

Mr. Goodrich. limit beyond which "the * * * arching effect is destroyed," and the arch action considered on page 610* can take place only over certain spans, the limiting value of which is not stated. This seems to be a most important omission, except that it is believed by the speaker that conditions are so variable that no precise limit can possibly be set in either instance. It would thus appear necessary in the first instance almost invariably to use for shafts such "bracing" as would be used "in an open trench," as suggested by the author for large shafts.

The author's reasoning on pages 611 and 612,* as to the effects of the angle of repose on arch action, is not at all clear. Furthermore, it seems to be based on entirely wrong assumptions, when the author states that there can exist a "tendency to slide along the angle of repose," using this phrase as he does synonymously with that of the "natural slope of the earth," as on page 600*. The experiments made by the speaker, and reported to the Society in his paper on "Lateral Earth Pressures and Related Phenomena,"† are believed to have demonstrated the existence of an angle of internal friction along which sliding will take place, which angle is usually very different from the angle of natural surface slope. Consequently, the author's work must be at least so modified as to include this angle of internal friction.

The ideas set forth by Mr. Haines approach nearer to those of the speaker than those of any investigator on this interesting subject. The speaker, also, has measured numerous slips—natural, and made by experiment—but has not found the hemispherical surface as accurately followed as one might infer was always the case, from Mr. Haines' descriptions. Arch action along lines which closely approximate circles is usually present in most soils, as soon as any movement takes place, and in this special point, such earth masses act like solids. But vibration, changing humidity, natural settlement, and lateral pressures bring about further movements among the particles composing the mass, so that an action closely analogous to the slow flow of a viscous mass also often takes place. Mr. Haines, however, takes no account of these possible changes of condition with lapse of time, although this is absolutely necessary in a complete theory. To be sure, a retaining wall which is stable under the author's or Mr. Haines' assumptions will be apt to stand under conditions like those usually assumed, but it does not seem to be good engineering to waste material in securing a needless excess of stability, as would seem to be the case in designing by either of the two theories mentioned.

As opportunity offers, the speaker is working out the combined theories of the several actions which occur in masses of earth, and hopes some time to present them for discussion. He doubts Mr.

Proceedings, Am. Soc. C. E., for August, 1907.
† *Transactions*, Am. Soc. C. E., Vol. LIII, p. 272.

Haines' analysis on page 1006,* which includes simply the volume and surface of a sphere. If the earth mass were supported on a shaft through the point, *B*, of Fig. 28, the reasoning might apply, but the mass which eventually moves actually rests with considerable weight on the earth beneath, which remains in position. Consequently, other forces besides pure shear enter the problem, and the speaker believes that Mr. Haines' explanation of the spherical surface of slip is not sound. Mr. Goodrich.

As to his analysis of the stresses due to the arch action, as he supposes it, attention should be called to the fact that the "center of gravity," as he expresses it, does not coincide with the center of length, as shown in Fig. 32, so that the stress, *T*, as found by him, is smaller than it should be according to the method he has adopted. There is also a grave doubt in the speaker's mind whether it is even approximately correct to assume that the lateral stresses against trench sheeting are such as would be produced by a series of arch rings between which no friction exists. It would seem rather more nearly according to reason and fact to assume a single ring of some thickness, just above the surface of fall, which ring is assumed to carry the weight of all the earth above it. This supposition would explain the shrinkage away from the sheeting near the surface, which the speaker saw on one occasion, coexistent with evidences of considerable arch action near the bottom. It also explains the concentrated pressures observed by the speaker on several occasions, and gives a reason for the fact that practically no pressure is found at the top of the sheeting, where it should be a maximum, according to the theories of the author and Mr. Haines.

Time, however, modifies most things, and it would not seem improbable that such concentrations would eventually distribute themselves, more or less, according to some law of variation of pressure. Such a readjustment of stress (described later) has actually been observed by the speaker.

An entirely satisfactory earth pressure theory has still to be evolved, and more phenomena can be explained on the assumption that earth acts like a viscous, partially elastic material, than on any other supposition. This hypothesis explains all the author's observations; explains the phenomena described above; and also throws light on the change in the position of the point of maximum thrust and the distribution of pressures observed by the speaker during one of the many earth pressure experiments he has made. The conditions and methods of test and analysis are given in the speaker's paper on Earth Pressures, previously mentioned. The initial observations showed a roughly triangular distribution of stress. A special condition was soon brought into play by a sharp thaw in the material be-

* *Proceedings*, Am. Soc. C. E., for November, 1907.

Mr. Goodrich.

hind the wall, and a considerably increased and practically concentrated load was observed near the top of the embankment. The point of application of this concentrated load then appeared to move slowly downward and was finally lost in the slightly parabolically distributed continuous load.*

While Mr. Meem is a most successful practitioner, and has done some very exceptional work, his theories with regard to earth pressures are not considered as well worthy of praise. It seems to the speaker, rather, that much more work must be spent on the problem before it is entirely solved, and that other lines than those followed by the author will lead to more consistent results. What might be called "Rankine's theory applied to a viscous granular material, wherein angles of internal friction are used," appears to be the most profitable course along which to investigate earth pressures and related phenomena.

Mr. O'Rourke.

J. F. O'ROURKE, M. AM. SOC. C. E.—The speaker has had a great deal of trouble in trying to do timbering work according to theory. Mr. Meem's conclusions are largely according to his experience in dry, sandy and gravelly material. It is only necessary to examine his diagram, Fig. 7, in which the pressures are indicated by parallelograms, with the largest parallelogram on top, to commence at once to find fault with his theory.

It is only necessary to consider that these pressures are transmitted through the material to show that it is impossible, at the top of an earth strut, so to speak, to get the greatest pressure, or a sufficiently great pressure, to require 12 by 12-in. timbers. If there were such a pressure as that, the material itself would rise, and the pressure would disappear. The fact is that in most cases this top timber may be taken out (barring, of course, strains which may be caused by other things than the pressure of the earth).

The real trouble with timbering, and all this protection of excavation, is that where there is something besides dry sand or gravel, there is water to be dealt with, and then the material has varying friction, and, of course, varying pressures.

The speaker had cases on Park Avenue, New York City, where 12-in. I-beams were bent. These beams were set vertically, and were perfectly straight until the ground had become more or less wet, and commenced to take a totally different angle of friction, thus becoming what is called "heavy."

With the statement that the pressures are the reverse of those caused by water, the speaker cannot agree at all. His experience is that it is almost impossible to drive sheathing beyond a certain depth because of the great pressure that develops the farther it is driven, and the fact that the timbers incline inward at the bottom owing to the increased pressure. No one who has done much sheet-piling in

* *Transactions*, Am. Soc. C. E., Vol. LIII, Figs. 11 to 16, p. 278.

excavations, particularly where there was water, will contradict that statement. It is a universal condition. Mr. O'Rourke.

The general question of experiments in earth pressures and their conditions which will reduce the subject to a science, is an admirable one. The speaker's opinion, however, is that such experiments would have to be continued for a thousand years in order to obtain something in the nature of a formula, but that formula would have a great many constants. There might be a number of what might be described as arbitrary, unknown quantities, but having had a thousand years' experience, it is possible that one might learn to use them. However, notwithstanding the great success in the use of formulas, up to the present time, the better plan is to stick as closely as possible to big timber, no matter what the formula indicates.

O. F. NICHOLS, M. AM. SOC. C. E.—In dealing with what may be called non-fluid earth, a semi-dry or quite dry material, not like a fine sand which will run, but more like the sand and loam found in New York City and on Long Island, there is much of value in the suggestions made by Mr. Meem. Mr. Nichols.

The angle of repose is determined by allowing material to run free in the open air; but, when it is flowing on itself, and has an angle of internal friction, so to speak, there is no doubt that the friction of the material tending to slide downward would set up some other angle of repose, or of partial stability, greater than the normal angle of repose and corresponding more nearly with the angle which Mr. Meem establishes as bisecting the complement of the angle of repose. Just what this angle is, is indeterminate, but, assuming that material does act in this way, the speaker has no doubt that Mr. Meem is right, that there is some arching effect with the skewback on one side which may be taken as the angle of repose, and on the other side by the sheeting of the trench.

This arching effect produces great pressure on the sheeting at or near the surface of the ground, and correspondingly relieves the pressure on the sheeting at points below, until, at the bottom of the sheeting, it is very often possible to undercut the sheeting, and to do this undercutting for long distances, and even to a great depth.

This arching effect, so far as it obtains, necessitates the use of heavier timbers at the top and lighter timbers at the bottom of the trench, and, where the material is not too wet and is not allowed to stand too long, so that water, the atmosphere, and other agencies can act on it, it is quite possible to leave the sheeting out for certain distances near the bottom of the trench. Constructors take advantage of this fact, for there is very seldom any shoring at the bottom of sheeting under the conditions assumed.

Engineers, however, must err if possible on the safe side, and it is probable that the old "angle of repose" conditions will still be used in

Mr. Nichols. earthwork calculations, mainly because it must be assumed that the worst conditions may prevail.

A man—who, of course, was not an engineer or in any way connected with engineering—recently asked for a discrimination between men like the late Professor Bartlett, of West Point, the engineer of to-day, and the contractor. The answer should be that men like Professor Bartlett develop the laws by which the forces of Nature act on material, the engineer applies these laws, and the contractor adds to the knowledge of the engineer the saving grace of common sense, and, particularly, introduces the element of commercial values.

When, therefore, engineers become successful contractors, the combination should, at least theoretically, redound to the great good of the community. The questions and solutions which Mr. Meem offers in his interesting paper are especially those with which engineering contractors should be familiar, and it is to be hoped that such men will take part in this discussion, for they, like Mr. Meem, have fought out engineering battles in close contact with the materials themselves, with their ears close to the ground, and they are men who measure problems by the laws of profit and loss as well as by those of engineering skill and efficiency.

The work in this field which Mr. Meem has done in Brooklyn, in supporting nearly a mile of elevated railway in full operation, in addition to the surface of the street and one of the busiest sets of trolley tracks in the world, and the work he did in restoring the grade on the Brooklyn end of the Battery Tunnel, certainly mark him as an expert in engineering construction, and his paper should be of great value, especially in bringing out discussion.

Mr. Gahagan. WALTER H. GAHAGAN, M. AM. SOC. C. E.—Those who have recently passed along Fulton Street and Flatbush Avenue, in Brooklyn, N. Y., cannot but admire the skill with which the subway work on these thoroughfares has been conducted. Credit for this work must be given to Mr. Meem, Chief Engineer for the contractors. The elevated railroad structures on these streets, from the City Hall to the Long Island Railroad Station, have been supported on temporary columns, for the full length of the excavation, and there have been no slips or settlements of the columns, and no interruption in the use of the tracks of the surface or elevated railroads.

Mr. Meem discusses pressures in dry, homogeneous earth, which conditions were found by him on this work, but, if hydraulic conditions are introduced, it becomes more difficult to determine the effect on the materials to be handled. The variety of materials is great, in all cases; they may be homogeneous, or may be mixed in any proportions, and may run through all gradations from dry to very wet.

The author does not intend that his formula for bracing, etc., shall be applied to all these various conditions, but only to cases where

the material is reasonably dry and homogeneous. Under other conditions, the speaker would be inclined to follow Mr. O'Rourke's advice and "stick close to big timber," and, further, in cases where there is much water in the soil, such timber should be used from close to the top to very near the bottom of the trench. A special study of the conditions is necessary in each case, and the speaker does not believe that any general formula for earth pressures is practicable. Mr. Gahagan.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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THE REINFORCED CONCRETE WORK OF THE McGRAW BUILDING.

Discussion.*

BY MESSRS. H. F. TUCKER, W. J. DOUGLAS, CARL GAYLER, J. A. JAMIESON, WALTER M. SMITH, AND CLARENCE W. NOBLE.

Mr. Tucker.

H. F. TUCKER, ASSOC. M. AM. SOC. C. E. (by letter).—Professor Burr and the contractors who erected the McGraw Building are certainly to be congratulated upon having designed and built a structure of reinforced concrete of such unusual height. The fact that the building did not collapse during construction, and is even getting stronger with age, ought to be encouragement enough for prospective builders who, perhaps, have become unduly prejudiced against building material of this class.

It seems important to the writer, however, that the fact should be brought out clearly—for prospective builders and for the Engineering Profession as well—that the structural features of the building were not designed by an architect or by a contracting firm. In no way is this statement intended to claim for the Engineering Profession any credit which is not due, or to place it above either of the others. It is simply intended to point out the success attendant upon harmonious co-operation between these three distinct professions: the architectural, the engineering, and the contracting.

The writer believes that it is only by each keeping strictly to his domain that the perfect can be most closely approximated. It is true that the architect must know considerable about engineering, in order that he may design a possibility, but he cannot be both architect and

* This discussion (of the paper by William H. Burr, M. Am. Soc. C. E., printed in *Proceedings* for October, 1907), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

engineer, nowadays, and excel in either. The engineer must know a great deal about construction, in order that he may design economically. A contracting firm should be purely a contracting firm, and not "contracting and engineering," though such a firm should employ competent engineers in its service, but not for the purpose of doing the work of the consulting engineer. Even in the cost-plus-a-fixed-sum system, where there should be no incentive to "skin," there is the temptation, if such a firm does the designing, to please the unsuspecting owner by providing a design based too evidently on cheapness rather than on proper strength. Mr. Tucker.

It is the writer's firm conviction that, had the McGraw Building not been designed by an independent, unbiased engineer, the success of such an undertaking would not have been assured.

Professor Burr has brought out in his paper many points in reinforced concrete design which are frequently overlooked. The most important point is the study of the design with a view to saving money by duplication and simplicity of form work. In steel construction it is usually found more economical to run one section of column up two or three stories before making a change. So, also, in reinforced concrete construction, especially in a design of this type, where much of the stress is taken by the steel, it will be found cheaper to vary the steel, and sometimes the mix, leaving the outside dimensions of the column unchanged for several stories.

Uniformity, as much as possible, everywhere, even in depth and width of beams and girders, will usually result in a big saving in labor. On the other hand, irregularities produce what might be called a very large coefficient of friction in the carpenter's mind, and his speed is reduced to a remarkable degree. Simplicity and duplication in the reinforcing will result usually in a large saving. The fewer bends in the steel, and the more pieces that can conveniently be made into a unit, the better. It has always seemed to the writer that the bending of floor rods is not economical practice. It is hard to hold the rods thus bent from tipping over, and especially with round rods, which are cheap; two layers of rods, one in the bottom of the slab and one in the top, both continuous, seem to be cheaper, especially for thin slabs and short spans.

It appears from the details on Plate XCIV* that every other slab rod is turned up over the beams, thus giving only half as much steel to resist the negative bending over the beams as at the middle of the span, where, if the author had been calculating on continuity, the moment is less than $\frac{Wl}{10}$. If this is the correct interpretation of the drawings, it would seem that there is either a redundancy of steel at mid-span or an insufficiency over the beams.

* *Proceedings*, Am. Soc. C. E., for October, 1907.

Mr. Tucker. The writer is in doubt as to whether it is economical to cast brackets under the ends of the girders and beams connecting to columns, as a brace against wind stresses, even in a high building, if it is as broad as the one under discussion. A deeper beam, if there is head room to spare, would simplify the forms, and make them more easily adapted to longer spans where the column section changes. When one sees a steel-framed building of ten or eleven stories and only 20 or 30 ft. from front to back, braced against wind by the ordinary web connection supplemented by 3½ by 2½-in. angle-lugs at the top and bottom of 20 or 24-in. I-beams, as was actually seen in Washington, D. C., he begins to wonder why a 30-in. reinforced concrete girder could not be connected to its column, far more stiffly and safely, by a few diagonal rods, and without the use of expensive brackets.

The removal of column forms, even with the substantial steel reinforcement in the columns of the McGraw Building, should not be reduced to the "minimum of time." To be sure, the lower columns would not have nearly all their dead load, but a column is a delicate thing, and really the backbone of such a structure.

In regard to such work being conducted successfully, under proper conditions, through a severe winter: The writer was connected in a professional way with a number of large reinforced concrete factory buildings for a manufacturing concern in Canada, last winter. Work was being pushed, as the contract time was urging the contractors to complete the buildings. It may not have been a severe Canadian winter, but it was far ahead of any Boston winter of the last two decades at least. The floors of the factory and shipping buildings were designed to carry a live load of 250 lb. In the spring the architect tested the shipping building floor "which suffered the most by frost, and it sustained a load of sand and stone of 450 lb. per sq. ft. without any deflection." It is probable that, through arch action in the load, or adjoining slab and beam action, the test did not show the actual strength of the floor; but, even so, it demonstrates the possibility of combating a cold climate successfully.

Mr. Douglas. W. J. Douglas, M. Am. Soc. C. E. (by letter).—In reading this paper the writer's attention was called, as it often is in considering reinforced concrete designs, to the apparent waste of steel when used as reinforcement for concrete-steel compression members. In this particular case, the writer refers to the columns, which are heavily reinforced.

According to the author, the lower columns contain 10% of reinforcement, which reinforcement carries 57% of the total load; while, at the ninth story, the reinforcement is reduced to 3½%, carrying at this point 30% of the total load.

On the basis of the assumptions stated, namely, 750 lb. compression for concrete and a ratio of moduli of 12, the steel in the

columns can only be stressed to 9 000 lb., plus some small erection stress. Mr. Douglas.

Now, considering the lower columns with their 10% reinforcement, assuming the cross-section of the concrete to be 625 sq. in., less about 56 sq. in. for the steel, it is found that the concrete in the columns is carrying a total load of approximately $569 \times 750 = 426\,750$ lb., and the steel, having a cross-section of 56 in., carries a total stress of 504 000 lb., making the total load on these columns 930 750 lb.

If, for this concrete-steel column, an ordinary steel column should be substituted, it would only require 58.2 sq. in. of steel. If it were possible, in the concrete-steel columns, to stress the steel up to 16 000 lb., only 31.5 sq. in. of reinforcement would be required, instead of 56.2 sq. in., therefore, there is a waste of 24.7 sq. in. of steel, or 83.9 lb. per lin. ft., which steel would cost about $3.36 per lin. ft.

In the ninth story, this amount, on the basis of the foregoing, would be reduced to about 60 cents. Assuming an average of $1.95 per ft. for steel wasted on account of its low compressive stress, there would be a total loss in the entire structure of about $13 600. (The writer, of course, acknowledges that this additional steel is an additional factor of safety, but the point that he is trying to bring out is, that it appears to be an uneconomical way of providing for a factor of safety.)

It is not the writer's intention to criticise the building in question, because he realizes that the circumstances were such that it was quite impossible to have saved this steel, yet he believes that in many buildings—and he is certain that in many bridges—it is possible to stress the steel in compression, both in columns and in girders, to about 16 000 lb. by designing the structure so as to make the steel in compression carry all or nearly all the compressive stress due to dead load, and he believes that this may be attained economically.

A case of a concrete-steel bridge (girder), now under construction in the District of Columbia, may be cited: On account of the limiting conditions, it was necessary to reinforce the compression chords of this bridge with a large percentage of steel. As the writer only stresses concrete in work of this class to 450 lb., he could not calculate that the steel in compression, under a design of the customary type, would carry more than 6 750 lb. per sq. in. The reinforcement consisted of two riveted trusses having a depth of about 6½ ft. The floor system also consisted of reinforced concrete, the beams of which were reinforced with built-up, steel I-beam sections, the full end shear in the beams being developed in the steel connections of the floor beams and main girders.

This type of reinforcement was selected by the writer for the following reasons: its ease of erection; the comparative certainty with which the stresses could be calculated; the certainty of having the steel located in the actual construction in accordance with the theoretical

Mr. Douglas. relation to the concrete; positive anchorages could be obtained for all members, particularly as to the connection of the web members and the chords; the girders have a small factor of safety in themselves; the forming work was simplified; the cost of depositing concrete was possibly decreased; and, because there was a great saving in the cross-section of the steel compression members on account of the practicability of stressing the steel in compression to approximately 16 000 lb.

The forms for the entire structure are to be suspended from the girder and from the floor beams. The design contemplates the jacketing of the floor system first, then the jacketing of the large girder, by which methods of procedure the steel girder will be made to carry almost the entire dead load, exclusive of the paving. The live-load stresses in the steel and the concrete will, of course, be distributed on the basis of the ratio of moduli.

In regard to the construction of large girders for bridges, which are exposed to the elements, it is thought that this method is a particularly good one because the amount of flexure in the concrete-steel girder is cut down to a minimum, therefore the possibility of the formation of incipient cracks on the tension flange of the concrete girder is also cut down to a minimum. Whether or not the formation of these tension cracks on exposed girders is a matter of import is, of course, a matter of conjecture rather than fact. It is believed that this principle may be applied to many buildings without unnecessary delay, and without an additional cost of forming.

In a second bridge, the writer is going to concrete the columns last, after the entire superstructure above the columns has been completed. In this way, the steel reinforcement, which consists of an ordinary steel column, will be made to carry the entire dead load.

Professor Burr, referring to the concrete in the columns, says: "As it is completely embraced or surrounded by the steel angles and lacing bars, it is steel 'banded' in the most effective manner possible."

The writer is rather inclined to believe that if the steel bands are not attached rigidly to the vertical reinforcement, a stronger column will be attained. His reason for this is that the concrete, in setting up, shrinks, particularly where the day's pour results in a long length of column, and soupy concrete is used, which is almost universal practice.

Now, as it is thought that this shrinkage takes place after initial set, it seems manifest to the writer that detached bands would give better results. As a matter of fact, it seems probable that the concrete adjacent to the vertical reinforcement will be injured more or less, on account of this vertical shrinkage, but this cannot be helped, and must occur even when plain round rods are used, unless they are mathematically straight. Therefore, it appears to the writer that,

with the same cross-section of steel and concrete, the ordinary star column, with detachable steel bands, would be stronger. Mr. Douglas.

CARL GAYLER, M. AM. SOC. C. E. (by letter).—The McGraw Building differs from the numerous purely reinforced concrete buildings which have been constructed all over the country principally in the type of the columns used. As described in the paper, these columns are built of steel angles, laced on all four sides and filled with concrete, and have been proportioned on the assumption, not only that both materials carry the loads jointly, but, furthermore, that through the lateral support afforded by the steelwork, the strength of the concrete is increased to such an extent that a unit pressure of 750 lb. per sq. in. —more than twice the pressure per square inch allowed by the Building Department of the City of New York on reinforced concrete columns—was deemed permissible. The unit pressure on the steel was then determined according to the ratio of the moduli of elasticity of the two materials (1:12). Such unit stresses in the columns permitted a height of eleven stories for the McGraw Building, with reasonable sizes for the columns, even in the lower stories and basement. Mr. Gayler.

Now, it is clear that if these assumptions were correct, that is, if the two materials of which the columns are composed were to act as a unit, with the additional advantage of greatly increased carrying capacity of the concrete, the superiority of such columns over the reinforced concrete column, in regard to reduced areas of cross-section, and safety, and over the steel column in regard to economy, would be so great that buildings constructed on the same plan, and of great height, would soon be generally built and become strong competitors of the steel skyscraper. But, are the claims for these combination columns justified? Not once in this paper is there mentioned the fact that concrete, in drying in air, shrinks. Waiving the question of relative changes in the dimensions of the concrete and of the steel under changes of temperature, or of the relative compressibility of the two materials under loading, the thoroughly established fact of the contraction of concrete in the process of hardening and drying remains. The phenomenal increase in the use of concrete for engineering works during the last ten years could not have taken place unless full account had been taken of this important quality of concrete. The exact amount of this shrinkage is unknown, but that the changes in the volume of concrete are considerable, probably greater than those under subsequent changes of temperature, is just as sure as that no corresponding reduction in the size and length of the steel column, put up in the building ready to receive the wet concrete, will take place. No amount of care taken in pouring and stirring will alter this inherent characteristic of all concrete used above ground.

Thus, in the McGraw Building, there are composite columns, about

Mr. Gayler. 150 ft. long, of varying cross-section, consisting of an outer shell of steel and filled with a material which, as any engineer who has had any experience with concrete knows, will at certain unknown distances develop shrinkage cracks. That the surface contact between the steel and the embedded concrete will have an influence on the manner of shrinkage, and therefore on the frequency and position of these cracks, is true, but to suppose that the latter are obviated through this contact is equivalent to assuming that the steel plates, angles, and rivet heads will, through their mere contact, stretch the enclosed concrete, uniformly, throughout the aggregate height of the eleven stories of the building. This would be a bold position to maintain, the more so because the contact between the steel and the concrete is not at all uniform: Throughout the greater part of the length of the columns the concrete is confined by angles and lace bars, with the rivet heads spaced some distance apart, while at the joints of the steel columns and, to some extent, at the points of lateral connections, it is solidly enclosed by angles and plates with closely spaced rivet heads.

To consider the influence of the inner surface of the rigid steel columns of the McGraw Building on the enclosed concrete, as far as shrinkage of the latter material is concerned, equal to, or even greater than, the effect of shrinkage rods of the ordinary reinforced concrete work, is a fallacy, because the shrinkage rod, owing to its light cross-section, partakes to some extent of the deformations of the concrete and, owing to its position inside of the mass of the concrete, is able to take up the stresses induced by the changes in form of the concrete, neither of which conditions is fulfilled by the steel shell. By deformations of the concrete is here meant not only the reduction of length, but also reduction of cross-section in the process of drying. The writer considers it anything but an extravagant statement to say that, in places, the concrete after hardening will not cling to all the four inner sides of the steel column.

To assume that the concrete contracts in such a manner that it forms a monolithic column, as high as the building, and bearing on the foundations in the basement, in other words, that the mode of vertical contraction of the concrete takes place as if there were no contact with the steel at all is, of course, out of the question and could not be maintained by the designers of this building for one moment, as in the paper great stress is laid on the "firm and complete hold or bond between the steelwork of each column and the concrete enclosed within it." The lace bars have been specially arranged so as to counteract such independent movement of the concrete as much as possible.

The above stated considerations have led the writer to the following conclusions:

1.—The McGraw Building is a reinforced concrete structure with composite columns, the carrying capacity of which columns consists in the steel.

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2.—The concrete filling of the columns is an excellent provision for the prevention of rust, highly advantageous, together with the concrete casing of the columns, in case of fire, besides affording some additional rigidity to the latticed portion of the columns.

3.—The wise provision, insisted on by the Bureau of Buildings of the City of New York, "that the cross-section of the steel in any column at any floor shall be sufficient to carry the entire dead load above that section without stressing the steel to more than 16 000 lb. per sq. in.," is, in view of the great weight of the building, a guaranty for the reasonable safety of the McGraw Building.

Mr. Jamieson.

J. A. JAMIESON, M. AM. SOC. C. E. (by letter).—Referring to the columns built of four steel angles, latticed diagonally, and the interior filled with concrete: The writer cannot agree with the author's claim that "the concrete is 'banded' in the most effective manner possible." In fact, he believes it to be obvious that the steel members of this column, as built, cannot possibly retard the lateral swelling of the concrete due to the compressive load upon it.

Assuming 12 to be approximately correct for the ratio between the moduli of elasticity for steel and concrete, and also assuming that each of the materials will take its computed share of the load, there will be an equal shortening of both the concrete and steel angles.

Now, it is well known that the transverse expansion of concrete under compression is very much less than the longitudinal shortening. Under a working stress of 750 lb. per sq. in., the former is probably not greater than 20% of the latter. With the lattice bars set at an angle of 30° from the horizontal, as the steel angles shorten under compression, these lattice bars, with their rivets acting as pivots, will force the angles apart, and the transverse expansion of the steel members will be much greater than the concrete, under which condition it must be obvious that the steel cannot band or restrain the concrete and thereby increase its power of resistance. In addition to this, it would be expected that the bond or adhesion between the steel and concrete would be destroyed.

If the steel angles had been connected by horizontal bars or battens, a much more efficient column would have been obtained; it would still, however, be far from "banded" in the most effective manner possible, since the thin straight bars, spaced at considerable distances apart, would not present material resistance to the lateral swelling of the concrete.

The column shown by the author cannot properly be called a reinforced-concrete column, but should be termed a composite concrete and steel column, having a strength in direct compression equal to the sum of the resistance offered by the steel and the concrete, using 12 as the ratio between the moduli of elasticity of the concrete and the steel, as required by the New York Building Code. Since, however,

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the concrete was placed in the work in a semi-liquid state, there would be considerable shrinkage during the setting and hardening period, which would most probably produce corresponding initial compressive stress in the steel and tensile stress in the concrete, and this would materially increase the load on the steel and reduce the load on the concrete and most probably cause the load ratio to become nearer 16 than 12.

The writer fully believes that reinforced concrete, as a structural material, is particularly well adapted for such buildings as the one under discussion, and does not contend that the column, as built, and under working stresses of 750 lb. for 1 : 2 : 4 unreinforced concrete, and 9 000 lb. per sq. in. for steel, is an unsafe one; in fact, he believes it to have an ample factor of safety, but he contends that the assumptions on which it is based are theoretically untenable, and are entirely at variance with all reliable information thus far obtained from tests.

The compressive member, or column, is probably the most difficult problem with which one has to deal, in the majority of structures, and it may not be out of place to venture the opinion that, up to the present time, the only rational reinforced-concrete column produced, in which the stresses are capable of being analyzed and closely calculated, and the one which gives the highest efficiency for the materials used, is that type in which the concrete is used in direct compression and the steel in tension only, designed to resist the lateral expansion of the concrete, thereby greatly increasing its power of resistance under compressive loads.

The tests conducted by M. Considére very fully proved the efficiency of this type of column, when properly designed and built. Subsequent tests conducted by A. N. Talbot, M. Am. Soc. C. E., have broadly confirmed the results obtained by M. Considére. Professor Talbot's tests, however, appear to indicate that the hooping remains inactive until a considerable load has been applied to the column, but it is believed that this is entirely due to the lateral shrinkage of the concrete, owing to insufficient water being attained, during the hardening period, to insure full crystallization.

It is true that many irrational designs of columns of this type have been produced and used; notably, those having a considerable percentage of longitudinal rods, with hoops or bands spaced at too great distances apart to prevent the lateral swelling of the concrete, with the consequent deflection of the rods and very high stresses in the bands, or those having spirals wound at too great a pitch, which increase in diameter with the shortening of the column, and also leave the concrete free to swell between the hoops. The hooped column, however, is gradually becoming better understood, and is being studied by many able engineers, and one may look forward to material improvement in the future.

WALTER M. SMITH, M. AM. SOC. C. E.—About three years ago, the speaker had occasion to observe the condition of stress of reinforcing steel bars in concrete. In constructing a battery of high-power guns at Charleston, S. C., the ceilings of the rooms had "Johnson" corrugated bars placed in the concrete, about 4 in. above the surface. The thickness of concrete from the ceiling to the top was about 10 ft., but at a height of about 2 ft. above the ceiling a water-proofing layer of asphalt was placed separating the concrete above from that below. The span, in the direction of the reinforcing bars, was about 11 ft. Bars were placed of a sufficient size, and at a proper distance to take all the tension, with the 2-ft. thickness of concrete acting as a set of beams 11 ft. in length. The bars were computed to be stressed in tension at 16 000 lb. per sq. in. Mr. Smith.

A few months after this concrete had been finished, it became necessary to cut a recess in the ceiling to a depth of about 1 or 2 in. beyond the reinforcing bars and about 2 ft. long in the direction of their length. When the concrete was cut from around the bars they sprang out of line, showing that they were in compression instead of in tension. In the speaker's opinion, the only way to explain this is that the concrete in setting had shrunk sufficiently to put a considerable compressive stress in the steel. The concrete in the lower part of the beam, therefore, was taking all the tension, and the steel could take none until the tension in the concrete became sufficient to cause it to stretch to the position it occupied when constructed. When this point is reached the steel begins to take the tension, and at a constantly increasing ratio as the concrete begins to develop fine hair-like cracks extending gradually upward from the bottom. The depth of concrete was very great in proportion to the span, in this case, therefore the proportion of steel was very small. The concrete on the tension side of the beam was not stressed very high in carrying the load, without considering the steel.

This is the only instance in the speaker's knowledge where concrete has been cut from around reinforcing bars and thereby a chance given to observe the condition of stress in the bars. He is glad, therefore, of this opportunity to bring it to the attention of engineers.

In view of the foregoing facts, it seems to the speaker that it is somewhat risky to construct long columns, as in the McGraw Building, with a large percentage of steel, and expect the concrete to take any portion of the load to the foundation. In the speaker's opinion, the concrete, being prevented from contracting longitudinally by the steel, will be in tension although it may show no appreciable cracks, and cannot, therefore, be relied on to take its due proportion of the load to the foundation. In the hooped column, if only enough longitudinal reinforcement be placed to hold the hoops in position during construction, the concrete is free to contract in setting and, therefore, is not in the same condition of stress.

Mr. Smith. The speaker believes that the fact mentioned by Mr. Goodrich, of the shrinkage of the concrete in the center of columns, reinforced as these are, goes to prove that the steel reinforcement does prevent the shrinkage of the concrete during setting and leaves it in a condition of tension.

Mr. Noble. CLARENCE W. NOBLE, ASSOC. M. AM. SOC. C. E. (by letter).—The writer has always been of the opinion that insufficient consideration has been given to the question of the proper division of the total bending moment into the positive moment, provided for in the center of the span, and the negative moment, provided for over the points of support. Every question, connected with the moment of resistance of a concrete beam, has been discussed until there is practicable agreement as to the actual conditions prevailing, and the only discrepancies of any moment are those arising from the fact that certain engineers, in their desire for simplicity, knowingly, prefer to ignore various phases of the matter. A far larger percentage of variation in the practice of different engineers is accounted for by the variation in the division between the positive and negative bending moments than in any other single consideration. In fact, this matter has come to the point where practice is now being crystallized by the adoption of building laws in various cities almost without any general engineering discussion of the question.

Obviously, with a uniform load distributed over several adjoining spans, there are a number of ways in which the total bending moment may be met. The system as a whole may be regarded as a series of simple beams, reinforced entirely on the bottom. It may also be regarded as a series of balanced cantilevers, extending out on each side from each point of support, and meeting at the center of the span, the reinforcement in this case being entirely at the top of the beam. By varying the quantity of steel at the bottom and top of the beam, it may be divided so as to be a combination of these two systems, with points of contraflexure located arbitrarily at the option of the engineer.

That this last statement is true, may be seen readily by a moment's consideration. The point of contraflexure in the first case—that of a series of simple beams—is directly over the point of support for each of the two adjoining spans. There is, in this case, no curve convex upward, and a cusp occurs at the point of support. This, of course, means that when fully loaded, a crack may be expected there. In the second case—that of a series of cantilevers—exactly the reverse takes place. There is no curve concave upward. The points of the contraflexure are concentrated at the center of the span, forming a cusp; and, under fully-loaded conditions, a crack will occur at the bottom of the beam at this point.

Now, by removing a portion of the negative reinforcement over the points of supports, these two superimposed points of contraflexure

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will be drawn apart and will approach the columns, and positive reinforcement will be required in the center of the span, in order to give the beam action over the interval between these points. Just how much positive reinforcement is needed will depend on the remaining amount of negative reinforcement.

As is well known, wherever the system of continuous beams extends indefinitely in either direction, the negative bending moment is represented by the formula, $\frac{W\,l}{12}$, and the positive bending moment by $\frac{W\,l}{24}$. This condition, however, only takes place when both the negative and positive bending moments are adequately met by moments of resistance, and then only when the unit stresses in the material furnishing this amount of resistance are the same at the center span and the points of support. As conditions vary from this, say by decreasing the moment of resistance over the point of support, thus bringing the point of contraflexure toward the ends of the clear spans, the curvature over the point of support is increased and consequently the unit stresses at this point are increased.

Only one condition is theoretically imposed for the division of bending moment between positive and negative points. This, as the total moment, must equal $\frac{W\,l}{8}$. The complement of $\frac{W\,l}{10}$, of the center span, as demanded by the Building Laws of New York City, is $\frac{W\,l}{40}$ at the point of support. This condition is actually required in French practice, although it seems to be largely ignored in the United States. If $\frac{W\,l}{12}$ is used at the center of the span, theoretically, then $\frac{W\,l}{24}$ must be used at the point of support; and if $\frac{W\,l}{16}$ is provided for at the center of the span, theoretically, $\frac{W\,l}{16}$ must also be provided for over the point of support.

Actually, one cannot "sail so close to the wind." If the French practice is followed and $\frac{W\,l}{10}$ is provided at the center of the span and $\frac{W\,l}{40}$ over the points of support, and if at any time actually theoretical conditions are realized, the reinforcement over the point of support will be stretched far beyond its elastic limit. Consequently, the actual bending moment at the center of the span will become $\frac{W\,l}{8}$. It is possible that this statement should be "taken with a grain of salt," owing to the fact that the beam may be incorporated into the general floor

Mr. Noble. system in such a way that, should an actual condition represented by $\frac{W\,l}{8}$ occur, the extreme bottom fibers of the beam would be confined so much at the ends that they would not have opportunity to elongate, and therefore an internal arching effect would be set up. If $\frac{W\,l}{12}$ be adopted at the center of the beam and $\frac{W\,l}{24}$ at the point of support, obviously the unit stresses over the point of support will be much greater than at the center of the span, thus bringing them probably very close to the elastic limit. If the actual theoretical condition is adopted, that is, $\frac{W\,l}{24}$ at the center of the span, and $\frac{W\,l}{12}$ at the point of support, the use of T-beams is prevented, as the section will not reverse, and it would be necessary to increase largely the depth of the beam at the columns and for some distance on each side. For this practical reason, the writer knows of no work in which this set of coefficients has been used.

There is another consideration, also, which prevents too close an adherence to any theoretical division of the total bending moment of $\frac{W\,l}{8}$. This is due to the fact that there are conditions of partial loading in which greater bending moments can be brought about in various points of the system than under strictly uniform load. If, for example, the beam extends over several panels, and the load is only imposed on alternate panels, intervening ones being occupied by aisles, it is questionable whether there would be any positive moment in the aisles, and it is certain that the bending moment in the centers of the spans taking the load would be considerably greater than $\frac{W\,l}{24}$. If provision is made for $\frac{W\,l}{12}$ at this point, therefore, and for $\frac{W\,l}{12}$ also, at the point of support, a system is adopted which will never meet the theoretical conditions occurring at the same time in actual practice, but which will meet any possible stresses occurring at any point in the system due to the variation of this theoretical condition. The resulting beam also has the advantage of being uniform in section.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

CHARLES EZRA HEQUEMBOURG,* M. Am. Soc. C. E.

DIED OCTOBER 17TH, 1907.

Charles Ezra Hequembourg was the eldest son of the Reverend Charles Louis Hequembourg (Yale, 1836), a distinguished Presbyterian clergyman and author, whose grandfather, Charles Louis Hequembourg, came to America from Rouen, France, in 1778. His mother was Emelia Williams Hequembourg, a direct descendant of Stephen Williams. Under the wise guidance of his parents, he began at once to cultivate the qualities he had inherited, and these carried him through a remarkably successful career.

He was born on July 9th, 1845, in what was then the Village of Dunkirk, Chautauqua County, New York, which place he always made his home, though for forty years his business interests were mostly in other fields. His education was received in the public schools of Dunkirk and Dansville, New York, and Warren, Pennsylvania, in which places his father successively established his home and reared a family of seven children. Forced by circumstances, it was necessary for him to begin the battle of life while very young, and he earned his first wages working in the summer on the farm, and during the winter season making boats and skiffs to be used in the spring by the lumbermen of that vicinity. As he grew older, his interest in work of this nature quickened until he finally took to the trade of carpenter. At the age of 18, however, he laid aside his tools, and, with Company D, 68th Regiment, N. G. N. Y., went to the front and later joined the Army of the Cumberland.

When he received his discharge, at the end of the war, he began to acquire his engineering knowledge, and practiced in Tennessee and Kentucky, where he soon had charge of the field work, surveys, mapping lands, drilling wells, building pipe lines, etc., for the Tennessee and Cumberland Oil and Mining Company.

In 1870 Mr. Hequembourg returned to Dunkirk, and entered the contracting business. His first large contract was the erection of what is now School Building No. 2, in that city. The next year he erected the first brick schoolhouse in Titusville, Pennsylvania. During 1871 and 1872, while filling the office of Village Engineer, he constructed the Dunkirk Water-Works, a direct-pressure system, costing

* Memoir prepared by Thomas W. Symons, M. Am. Soc. C. E.

about $100 000. In 1873 and 1874, as engineer and contractor, he constructed the water-works systems of the Towns of Hyde Park and Lake, now part of the City of Chicago. These were also direct-pressure systems, and cost about $1 250 000. Later, at Bradford, Pennsylvania, he erected the St. James Hotel building, the second brick edifice that city possessed, and now its principal hotel. As a direct result of his location, he naturally became interested in oil developments, and was one of the early operators in the Pennsylvania field. He took special interest, however, in natural gas, of which he made an exhaustive study, and to the end of his life was an authority on all matters pertaining to the production and use of gas.

In 1878, as President and Engineer, with associates, Mr. Hequembourg organized the Bradford Gas, Light and Heating Company, and the Tarport and Kendal Gas Light and Heating Company. These were the first corporations to supply natural gas for light and fuel to a municipality. The original supply was obtained from natural pressure, but in 1880 this was superseded by a pumping station at Rixford, Pennsylvania, with a capacity of 6 000 000 cu. ft. per day. It was from the experience and knowledge thus acquired in the Pennsylvania fields that, in 1888, as President and Engineer of the Columbus Construction Company, he was able to undertake the task of connecting Chicago with the gas fields of Indiana, and in this undertaking he was most successful. In 1892, the Columbus Construction Company completed and turned over, to the owners of the Indiana Natural Gas and Oil Company, and the Chicago Economic Fuel Gas Company, what was then the largest and longest gas pipe-line system in the world. Fully equipped with modern pumping stations and appliances, this pipe-line is now in successful and profitable operation.

Mr. Hequembourg was strictly a self-made man. His parents, with a large family to rear, and with a limited income, were unable to give him the advantages he lived to give his sons and daughters, and from an early age he began to face the stern problems of life. He looked about him, saw his opportunities, and grasped them, and the secret of his success was that he always investigated thoroughly any matter which was of interest to him at the time. His mind was extraordinary, and drifted naturally into scientific channels, although he often remarked that his greatest ambition was to be a lawyer, and, in representing his associates or in his own work, he took actual delight in probing into the depths of the legal questions which were presented. He possessed a complete law and reference library, in addition to his collection of scientific works, and his friends often accused him of never being content unless he had a lawsuit on his hands.

After retiring from active practice, in 1892, he took up his home life at Dunkirk, and to gratify his longing for scientific research and knowledge, he erected near his residence an observatory consisting of

a tower 65 ft. high, in the top gallery of which, mounted on a brick pedestal, was placed a 25-ft. telescope, with a 9-in. objective. This observatory is fitted with all modern appliances, instruments of precision, etc. On the other floors of the tower are arranged the library, photographic room, and laboratory. It was here that Mr. Hequembourg loved to entertain his friends and enjoy his astronomical work until, unfortunately, in 1901, he slipped on an icy pavement and fractured his leg. After that he was not able to climb the tower stairs without considerable annoyance, and he was forced to give up his work in this field. Not content to remain idle, however, he became interested in automobile construction, and, a few years ago, took out a patent on an improved non-puncturable tire, but not until he had made many long and serious tests of his idea.

Mr. Hequembourg was a devoted and loving husband, and a kind and indulgent father, and was very happy in his home life, constantly striving to make his family comfortable and happy.

In March, 1904, he was selected by the people of Dunkirk as their Mayor. His election was not of a political nature, but was due rather to a movement for reform, and his administration was marked by an increase in local patriotism.

The following term he was on the ticket of both parties, and carried the city through another season of prosperity. His attention to municipal affairs was marked by the energy and earnestness with which he conducted his office. One of his fondest hopes was to live to see Dunkirk become a large city, and he believed that, on account of its natural advantages, it could be made so by proper co-operation. Dunkirk Harbor was the subject of special interest to him. At one time, at his own expense, he made surveys and soundings of this harbor, and brought about a public movement to get Congress to appropriate sufficient funds for the proper deepening of the channel and anchorage, and its protection by suitable breakwaters. This was accomplished, to a great extent, but Dunkirk needs another man, such as she has lost in Mr. Hequembourg, to come to the front and direct the gathering of the fruits of his labors in this field.

Mr. Hequembourg had been in excellent health all his life until last March, shortly after the death of a beloved son, Louis Max Hequembourg, a boy of 22 years, and a Junior in the College of Civil Engineering at Cornell University. The loss of this happy boy, whose future seemed so bright, and of whom he was so proud and hopeful, completely broke his heart, and from that day in March, when his boy was taken from him, he appeared to decline, and seven months afterward followed him to Fredonia, where he lies near him in the family plot in beautiful Forest Hill.

At St. Louis, in 1872, Mr. Hequembourg was married to Harriet E. Thurber, who survives him, with their son, Charles Guy Hequem-

bourg, an engineer in New York City, and their four daughters, Mrs. J. L. Hurlbert, of Dunkirk, Mrs. F. K. Wing, of Buffalo, and the Misses Jessie and Hilda Hequembourg, who live at home.

Charles Hequembourg was a man of great activities. Always thoughtful, conservative, and unassuming, he possessed great determination, and once having mapped out a course of action, no obstacle seemed so great as to be unsurmountable. He planned and solved large business problems with the skill of a master, in the fulfillment of which he crossed swords with many of the great captains of industry, and in the action was seldom, if ever, worsted. He commanded the respect of his associates, and all men with whom he came in contact, no matter on which side they stood. A large man, physically, he possessed a heart large in proportion, and was always sympathetic, kind, and courteous to all. He was surely one of God's noblemen. He possessed, in a marked degree, the qualities of self-reliance, courage and inflexibility of purpose. If these characteristics are applied to the branches of activity wherein his energy found an outlet, it is easy to understand why he was a successful engineer, and an instrument in the development of large interests, and why he has left behind him so many who will mourn his loss.

Mr. Hequembourg was a Thirty-third-degree Mason of the Ancient Order of the Accepted Scottish Rite. He was elected a Member of the American Society of Civil Engineers on June 5th, 1901, and, although he took no active part in Society matters, he was a close observer of all that transpired, and took the greatest pride in his membership.

PAUL ERNEST OBERNDORF, Jun. Am. Soc. C. E.*

DIED OCTOBER 13TH, 1907.

Paul Ernest Oberndorf was born at Centralia, Kansas, on February 16th, 1885, and died of typhoid fever at the same place after a short illness, on October 13th, 1907.

His childhood and early youth were spent on the farm. In the autumn of 1900, he entered the Friends Preparatory School at Washington, D. C., and was graduated with honors in 1902. He entered Princeton University in September, 1902, and was graduated four years later with the degree of Civil Engineer. His record in college was of such character that, upon his graduation, he was offered an assistant professorship, but he chose rather to enter at once into the practical work and experience of his profession.

* Memoir prepared by L. R. Ash, M. Am. Soc. C. E.

He was first employed by Messrs. Waddell and Hedrick, of Kansas City, Missouri, as an assistant engineer upon the large viaduct, then building, between Kansas City, Missouri, and Kansas City, Kansas. After a short time he was sent as an assistant engineer on the substructure for a bridge over the Atchafalaya River, in Louisiana. This position required a man of judgment and precision, and Mr. Oberndorf did his work in such a manner as to mark him as a man of rare tact and ability for one so young. For the few months before his death, he was employed as draftsman in the office of Ira G. Hedrick, M. Am. Soc. C. E., and here, as in the field, his work showed him to be original and resourceful. Judging from the results of the little more than a year's work between his graduation and his death, Mr. Oberndorf undoubtedly had the qualities of a great engineer.

Mr. Oberndorf's temperament was a most happy one, his manner was cordial and friendly, and showed regard for the opinions and feelings of others. It is rare that one finds a more symmetrically developed, well rounded out man, in the highest sense of the term. His death was a great personal loss to his host of friends, for all who knew him loved him and were drawn to him by his gentleness, his manliness, and his magnetic personality.

Mr. Oberndorf was elected a Junior of the American Society of Civil Engineers on February 5th, 1907.